Oeuvrie Y.

PROSPECTUS

OF

A SERIES OF NEW WORKS,

ENTITLED THE

AMERICAN LIBRARY OF HISTORY;

NOW PUBLISHING BY

COLLINS & HANNAY AND W. E. DEAN.

Of all the numberless improvements which distinguish our age, there is none more remarkable, and more widely beneficial in its influence, than the introduction of a cheap popular literature for the use of those whose occupations or means deny them access to the larger and more expensive works which alone were thought worthy, but a short time ago, of the labours of the closet or the honours of the press. Among the high merits of the most enlightened statesman of his generation, is noted the creation of this valuable instrument of moral and intellectual advancement; and the name of Brougham is associated in some manner with more than half of the publications which, at reduced prices, are now finding their way into houses in which the luxury of reading was, but a few years before, confined to a single book, or entirely unknown. In America, the advantages of such a literature must be strikingly apparent when we reflect that the only recognized distinction among us is the distinction of merit, and the only inferiority of the lowest orders, is an inferiority of knowledge occasioned by the difficulty or the impossibility of its attainment.

Within a very recent period efforts have been made by enterprising publishers to reproduce here, for the benefit of their countrymen, the works of English writers in this new and most useful department of letters. To these efforts the public have corresponded in such a manner as to testify their full appreciation of the service, and of the intrinsic excellence of the design. The "Family Library," the "Cabinet Cyclopædia," the "The Cabinet of History," with several others devised to the same end, and in the same spirit, have vindicated by their success the efficacy and the merit of the plan; and if the public-spirited projectors in this country have in some measure reaped the fruit of their risk and their labour, they have but received the just reward of a public benefaction.

Yet with all the excellences of the many works now offered to the world, with the laudable desire to extend among the poor and the young the advantages of education and knowledge, it appeared to the Proprietors that something still remained to be done; something without which the contemplated work of improvement could never be complete. The tone of even liberal writers in England cannot be expected to come up to that standard which in the United States would be required to harmonize with the character of our institutions; but it is a fact, which will not be denied, that of those very writers, whose literary eminence entitles them to a reprint in this country, the greater

number are of that class who inculcate opinions and doctrines the reverse of those which, as Americans, we should desire our children to imbibe. It cannot be desirable that the early notions of those who will derive their principal stock of general knowledge from publications of this kind, should receive them coloured with the prejudices of writers who have grown up in the midst of institutions, habits, and prepossessions opposed to those which the interests of this republic require in its citizens, or that their sentiments in regard to great political and moral revolutions should be shaped by the opinions of men who have formed their own conceptions of things on the data presented to them by the history of the old world, and who are unwilling or unable to concede their due authority to the influence of American history, American manners, and American institutions.

To supply the desideratum, which the best collections have thus left, in our cheap and popular literature, the Proprietors have embarked in their present enterprise; and they offer their series, "THE AMERICAN LIBRARY OF HISTORY," with a full conviction, that if the execution of the several works shall merit the public approbation, they will not fail to receive that patronage upon which the success of their experiment must depend. The peculiar characteristics of this publication will make themselves manifest in its name; and the Proprietors conceive that they have already sufficiently justified, in their reasons set forth above, the admission of American productions alone into their collection. In confining themselves to Historical subjects exclusively, they also believe that they are best consulting the wants and wishes of the community, inasmuch as all the publications of this kind which have preceded theirs, have been miscellaneous in their nature, and have nothing in their character to constitute a series, with the exception of the uniformity of their outward appearance. By the means now proposed, it is obvious that works which are not calculated to promote the ends of general knowledge will not by any accident find a place in their list; and that when their series shall have embraced the history of nations, or when it shall, in other words, have come to constitute a cheap and popular universal history, it will be brought to a termination. The lives of individuals, as being too limited in their bearings, will not be considered as possessing historical value, unless their history be the history of their times. Indeed, it must be evident, that if the biography of individuals can be admitted, the series cannot be brought to a close until the life of every illustrious character shall have had its separate tribute. The life of Wickliffe, of Alexander the Great, of Mahomet, of Buonaparte, is history; the lives of Nelson and Belisarius, are memoir and biography.

In regard to their plan, the Proprietors need only observe in conclusion, that it will be their aim to furnish, in the works which they are now about to offer to the Public, an historical library, sufficiently detailed for all the purposes of the general reader, and in a form sufficiently attractive to engage his interest and secure his attention. The numbers already in preparation are:

A HISTORY OF THE TURKISH EMPIRE IN EUROPE;
A HISTORY OF FLORENCE;
A HISTORY OF THE NORTHERN NATIONS OF EUROPE; and
A HISTORY OF PERSIA;

upon which some of the ablest writers of our country have employed their pens. The editorial department of the publication is entrusted to the charge of LORENZO L. DA PONTE, *Professor of Italian Literature in the University of the City of New-York*, from whom the Proprietors feel confident in assuring the Public it will meet with a faithful attention and assiduous care.

S. Hartridge
1837

ELEMENTS

OF

PHYSIOLOGY:

BY

A. RICHERAND,

PROFESSOR OF THE FACULTY OF MEDICINE OF PARIS, MEMBER OF THE ACADEMIES OF VIENNA, PETERSBURGH, MADRID, TURIN, &c.

Translated from the French

BY G. J. M. DE LYS, M D.

FIFTH EDITION.

CAREFULLY REVISED AFTER THE NINTH AND LATEST FRENCH EDITION, AND SUPPLIED WITH

NOTES AND A COPIOUS APPENDIX,

BY

JAMES COPLAND, M.D.

LECTURER ON PHYSIOLOGY, PRINCIPLES OF PATHOLOGY, AND THE NATURE AND TREATMENT OF DISEASES; CONSULTING PHYSICIAN TO QUEEN CHARLOTTE'S LYING-IN HOSPITAL; SENIOR PHYSICIAN TO THE ROYAL INFIRMARY FOR CHILDREN; MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS, LONDON, &c.

SECOND EDITION.

NEW-YORK:

W. E. DEAN, PRINTER, 70 *FRANKFORT-STREET.*

COLLINS AND HANNAY; COLLINS AND CO.; SAMUEL WOOD AND SONS; AND GRIGG AND ELLIOTT, PHILADELPHIA.

1833.

TO

HALLIDAY LIDDERDALE, M.D.

MEMBER OF THE ROYAL COLLEGE OF PHYSICIANS, LONDON, &C.

THIS REVISED EDITION,

THE NOTES,

AND

THE APPENDIX,

AS AN ACKNOWLEDGMENT
OF HIS PRIVATE AND PUBLIC WORTH,
OF HIS PROFESSIONAL AND SCIENTIFIC ATTAINMENTS,
AS WELL AS
A SMALL TESTIMONY OF GRATEFUL RECOLLECTIONS
OF HIS VARIOUS ACTS OF KINDNESS,

Are respectfully Inscribed

BY THE EDITOR.

PREFACE

TO THE

PRESENT EDITION OF THE TRANSLATION,

AND OF THE

EDITOR'S NOTES AND APPENDIX.

The Editor has endeavoured to revise the present edition, as carefully as was in his power, after the latest French edition. He has been anxious to get rid, as far as he could, of the foreign idiom and obscurities which he found in the translation ; and he has introduced whatever new matter could conveniently be added to the body of the Work. He has made considerable additions to his Annotations, as well those which accompany the author's text, as those which form the Appendix. In order that the Work should not be too bulky, the Editor has enlarged the page much beyond the size of that of former editions. He has generally refrained from adducing in his Notes old or obsolete opinions, in order that he should have sufficient space wherein to discuss modern doctrines, and to state his own views.

The former edition of the Editor's Notes contained opinions which he is not aware to have seen previously published, and which, indeed, were opposed to those generally believed in, even by the latest observers and writers. Many of these opinions have since received confirmation in the researches and writings of various continental physiologists. The reader will find them discussed as fully as the limits of the Notes could admit. The Editor, however, has still hopes of being able to bestow upon them these illustrations, and to give them that degree of developement, which they still require, and to consider them in their relations to the nature and treatment of diseases. This, however, cannot be satisfactorily performed on an occasion like the present, but must be made the object of a separate undertaking.

1, *Bulstrode Street, Welbeck-Street,*
Cavendish Square,
9th May, 1829.

THE

EDITOR'S PREFACE

TO THE

FIRST EDITION OF HIS

NOTES AND APPENDIX.

The Author of the Notes to this Edition of the English translation of M. Richerand's Elements of Physiology has endeavoured to give a full, but concise account of the opinions recently offered on some of the topics embraced by the Work. He has not, however, confined himself to the bare detail of the views of others—he has frequently stated his own opinions. In doing this he has been as concise as the nature of his subjects would allow him.

The office of an Annotator has not permitted him to bestow that copiousness of illustration on his own views which many may consider them to require: this will be attended to on another occasion. In the meanwhile, in whatever manner his opinions may be received, he will not shrink from a fair discussion of them; he will always respect, and endeavour to profit by, a candid examination of them; and he will espouse them no longer than he is perfectly convinced that they are founded on a correct interpretation of the operations of the animal economy.

1, *Bulstrode Street,*
5th June, 1824.

THE

TRANSLATOR'S PREFACE.

It is a singular fact, that in this country, which has given birth to some of the most important discoveries in physiology, there should not have been produced a single elementary or systematic work on the subject. Those only have written on physiology who had discoveries to make known, and to these they have, in general, confined their publications. The consequence has been, that there are, in the English language, many works in different departments and on single points of physiological inquiry, and that our miscellaneous scientific publications, the transactions of societies, and periodical works of inferior importance, are stored with much valuable matter, both of new facts and original speculation: but till this is brought together, from the various quarters where it lies scattered, into some more comprehensive form, it is not truly within the reach of those to whom it would furnish an important part of their professional knowledge; nor, indeed, until it possesses some systematic work, embracing all that is known of the subject, can the country itself exhibit its claims on the scientific world for the service it has done to physiology.

Such a work, however, which should fairly represent the state of physiology as it at present exists in Europe, was perhaps scarcely to be expected; for though it should contain no discovery, it would be, if rightly executed, a work of great magnitude, and requiring qualities which do not often go together. The industry requisite for collecting materials from so great a number of writers in different languages—the judgment and profound knowledge of the subject necessary in the selection—the acuteness required in arriving at the truth, where the variety of opinions is so great,—are qualities rare in themselves, and still more rarely combined. The genius which inspired to the great English physiologists the important discoveries that have immortalised such names as Harvey, Hunter, Monro, seems as if it had unfitted them for the more laborious and ungracious task of compiling and arranging the discoveries of others. How seldom may we expect to meet with such a combination of genius and indefatigable industry as was seen in the great Haller; yet without a certain degree, at least, of the same qualities, no writer can pretend to tread in his footsteps.

It is probable, too, that the great work itself of Haller, at the same time that it best illustrates the importance of the undertaking and its difficulty, must be considered as having long remained, by its excellence, an impediment to the production of a similar succeeding work. Haller was fifty years engaged in the most ardent study of physiology: his work, besides all that he himself, the great leader in physiological discovery, and also the most extensive discoverer, wished to give to the world, of his own, contained all that was known on the subject at the time it appeared. As it was written, too, in the Latin language, it found a ready access to every school of medicine, and was every where received by the profession as, at once, the most authentic record of the facts of physiology, and the most luminous exposition of the principles of the science. We cannot wonder, therefore, that while Haller had exclusive possession of physiology, no other writer should have attempted any work on the same subject, even for some time after his death, while the additions to the mass of knowledge were not sufficient to effect any important change in the science. Now, however, enough has been added to change, in many important respects, the face of the science, and to demand systematic arrangement. Of late years, accordingly, several works, composed with this view, have appeared on the continent; amongst which may be mentioned those of Blumenbach, Bichât, Dr. Dumas of Montpellier, and M. Richerand.

This priority in the systematic arrangement of our knowledge does not, however, at all imply that the progress of physiology abroad has been more rapid than in this country. It would be difficult to say where it is furthest advanced. If a comparative view were to be given of the science, as it exists in Britain and on the continent, it would rather appear that a different excellence has been attained on either side, accompanied, of course, by different defects. In Britain, it might be shewn that it is founded on sounder principles, and more freed from the doctrines of the older physiologists, who were rather given to invent explanations of the phenomena of nature, than to seek them in the laborious investigation of her operations. The physiologists of this country have studied with intelligent, patient, and zealous research, the facts of physiology; they have distinguished themselves in this, as in

the other sciences, by an anxiety for exactness of knowledge. The continental physiologists are fond of theory; an adherence even to the old theories characterises, very remarkably, the works of the most modern foreign writers on medicine and surgery, influencing even the practice of the profession in a very unfavourable manner. But this spirit of theorising—this anxiety to extend individual facts into general principles, is as essential to the progress of the science, as that zeal in the acquisition of knowledge which prepares its materials. They carry this spirit to excess; but which is the most dangerous error to science I will not pretend to determine—that impatient activity of mind, which, in its eagerness to theorise, will not wait for fulness of knowledge,—or that over distrust of theory, which is not judicious caution, but timidity, or indolence, or a real want of intellectual disposition to high philosophic speculation.

The same comparison would shew a superiority in another respect, in the physiologists of this country—that they have made further progress in *pathological* physiology. They have applied themselves more to the study of nature under disease, investigating both the disordered functions and the altered structure of disease, and seeking to understand, and successfully availing themselves of, the powers of renovation and substitution, which are provided in the body for injuries of its original organisation; drawing, in short, from physiology a light to the intelligence and practice of their art. The continental physiologists, on the other hand, have rather endeavoured to bring light from other sciences to physiology. And though here, too, their speculations have borne the same character of precipitancy, there is no doubt their labours in this department have been attended with considerable success; and that while many of their applications and analogies have passed away from the public mind almost as soon as they were before it, much still remains that will be permanently received as convincing illustration, from the sciences of inanimate matter, of the processes of living nature.*

This different direction of the spirit of inquiry in different countries, has probably been favourable to the rapid progress of the science. Yet something has been lost to it by what was not at all a necessary consequence of such a division of labour, a disregard of each other's pursuits and acquisitions. Both here and abroad, we have every day discoveries brought forward by writers, who are very legitimate discoverers, if real ignorance of the previous knowledge of others entitle to the name of originality. These imagined discoveries are prosecuted with infinite zeal, and much good labour is lost to physiology, in bringing facts to light that were well established in the world before these authors were born. The Work now given to the public can scarcely be offered as a remedy, as far as this country is concerned, of the inconvenience; for though it contains a good summary of the knowledge and opinions of modern physiologists, and does very fairly represent the present state of the science on the continent, those who really desire to possess themselves of what has been done there will be aware that they must undertake a much more laborious study, and seek for the information they want, in most cases, at its original sources.

This work, I believe, will be chiefly useful for the purpose which was designed by the author,—as an elementary book for students. There is not, as I have said, one English elementary work on physiology; scarcely, indeed, on any part of our professional knowledge. Whether it be that there is more literary industry abroad, or that in the institutions for medical education the public teachers are more separated from their profession and devoted to the duties of instruction, it is certain that in all departments of professional study they have distinguished themselves by the number and ability of their elementary works; and in the science of physiology in particular, the English student who is desirous of engaging in it will find himself at a loss for a guide, among the names that have done honour to science at home, and compelled to seek assistance in his pursuit from the writers of other countries.

An eloquent modern writer on anatomy complains that too much attention is now bestowed on physiology, while anatomy, on which sound physiology ought to rest, is neglected. That anatomy ought to be made the ground-work of all medical education, and that a thorough knowledge of the structure of the human body ought to precede the study of its functions, is indisputable; nor does the truth of this opinion appear to be denied by any one in the present day: and, accordingly, anatomy appears every where to be cultivated with ardour. In all places of medical education, the number, both of teachers and students of anatomy, is increased in much greater proportion than in any other department of professional study. Dissection is now considered as essential in the study of anatomy, and almost a new system of minute surgical anatomy has been instituted within a few years.

* It was in the contemplation of the translator, when he undertook this Work, to have engaged, in some degree, in the comparison of which he has here spoken. He intended to annex to it, in the form of an Appendix, a comparative view of the opinions entertained in this country, and on the continent, on many interesting points of physiology, which might serve the purpose of notes to the work, and be some compensation to himself for the unsatisfactory labour of translation. It is not till towards the close of the work, of which the translation and printing have been unavoidably going on together, that he finds the time to which it was of importance to the publisher to fix the publication, does not allow him to complete his original intention.

There appears no reason, then, to complain that anatomy has been neglected; and if there were, it is not to physiology the neglect could be imputed. The number of teachers of anatomy, of medicine, and surgery, is more than four times what it was half a century ago, but the number of teachers of physiology remains nearly the same. Physiology is either not taught at all, or forms a very insignificant part of a course of anatomy. A professed course of physiology is, at present, scarcely delivered any where out of the metropolis; and even there, only one lecturer is found to undertake such a course. It is not true that in this country physiology absorbs too much of the attention of students, and interferes with more important studies; it may rather be said to be too little attended to as a branch of instruction: it is omitted until the engagements of the profession leave no time for the prosecution of a laborious study; and it is, in the end, neglected altogether. If physiology, if the knowledge of the healthy functions, be necessary to him whose object in life is to understand the functions of the body in disease, it is of consequence that physiology be more generally studied, that it be considered more as an essential object of professional education, that our public teachers bestow on it a greater share of their attention.

Let it not be objected to the public teaching of physiology, that it may be learnt from books as well as from lectures. The objection, if valid, would be equally applicable to most of the other departments of professional study, the objects of which do not admit of ocular demonstration; yet no one objects to lectures on medicine, materia medica, &c. This study, however, does require the frequent illustration of anatomy, of drawings, of preparations, and even of experiments, which are within the reach of few. The study of physiology in books alone is dry and uninteresting to the young student, and will never be prosecuted with ardour. It seems too much to rely on the capacity for solitary study of young minds; and, at all events, the study of physiology, as of any other science, by a number of young men under one teacher, will be more ardent, from the frequency of discussion and experiment, than if carried on by each separately. To study physiology with any effect, the student should have access to public lectures on the subject, in which he will see experiments and preparations, besides such dissections in human and comparative anatomy as may be required to illustrate the doctrines he hears: he will then be qualified to turn his private studies to account, and will pursue them with interest.

Haller, who may justly be termed the father of physiology, was himself a distinguished lecturer, and his mode of instruction may be safely followed. He was a pupil of the celebrated Boerhaave, and when he himself became a public teacher, the doctrines of that great man had possession of the schools: these doctrines he tells us, in his preface to the Primæ Lineæ Physiologiæ, he continued to teach for twenty-four years, using the work of his illustrious teacher, as he calls him, for his text-book; but finding that since the time of Boerhaave many improvements and discoveries had been made in the science, he thought it right to substitute an elementary work of his own, containing the more recent discoveries; and this work he addressed to his class. Physiology is improving, and new discoveries are daily added to the store of knowledge already in our possession. If all these scattered materials were brought together, a work might be grounded on them of the highest value to the public teacher who has to communicate instruction, and to the student who has to meditate, in private and at leisure, on the knowledge that has been rapidly communicated to him in a public lecture. This object is, as was already observed, in part fulfilled by the work of M. Richerand, though incompletely as far as respects this country, as it does not embrace sufficiently the state of the science in Britain.

Birmingham, Sept. 14, 1812.

THE

AUTHOR'S ADVERTISEMENT

TO

THE FIFTH EDITION.

In preparing for the press this Fifth Edition of his Work, the Author has carefully revised and corrected it, in all its parts, so as to render it more worthy of the success it has already obtained. The additions which have been made will be found not to consist of idle discourses or frivolous hypotheses. The ground-work and the order are the same, the Author has merely added to the mass of facts,—supported, by additional proofs, the opinions which he had advanced,—and developed those parts of his subject, which, from being explained in too concise a manner, might be involved in some degree of obscurity.

Among the variety of opinions which criticism, oftener unjust than enlightened, has pronounced, in judging this Work, there is one which requires to be refuted, because it proceeds from an erroneous idea of what an elementary work should be. The Author, it has been said, ought to have contented himself with giving a view of the present state of the science, without any additions of his own; and he should have abstained from inserting new opinions, which, until they had received the sanction of the learned world, ought not to have been introduced into an elementary work. This objection may be answered by considering that modern physiology being, in some measure, a new and regenerated science, there will be found, in treating of it to its full extent, many deficiencies to be filled up, and many doctrines evidently erroneous for which truths are to be substituted, which it is of importance to discover. Lavoisier, in his Elements of Chemistry, set forth, in a methodical order, truths which he himself had discovered: he introduced original ideas, not such as owe an appearance of originality to minute explanation of what is already known, or to a general want of erudition, too prevalent in the present day. One of his most illustrious colleagues, in describing the state of the science, has likewise given a history of his discoveries and labours, and men of the soundest judgment ascribe the astonishing progress of chemistry, in a great measure, to the favourable circumstance of our possessing elementary works written by the most distinguished chemists.

The present work has been translated in England, in Spain, in Italy, in Germany, and men of merit have not disdained the task. Since the publication of the Fourth Edition of this Work, Professor Sprengell has published his Institutes of Physiology.* The date of that new work, and the well-deserved reputation of its author, entitle it to be considered as a faithful account of the state of physiological science in Germany. In that work the reader will be astonished to find it stated that every thing in the human body is governed by *polar influence* and by the laws of *antagonism;* that man is in a state of *positive electricity;* that his body is formed chiefly of *oxygen;* while the female body is in a state of *negative electricity*, with a superabundant quantity of *hydrogen* in the composition of its solids and fluids. Thus, by the premature application of a few facts borrowed from the physico-chemical sciences, the learned of Germany have thrown back physiology into the uncertainty of conjectures and hypotheses.

On the other hand, Gall, by his anatomical discoveries on the organisation of the brain and nerves; and a few other physiologists, by their experiments on living animals, have been usefully employed in advancing the progress of physiology. The Author has been anxious to increase the value of this new edition by adding to it the result of their observations.

* *Institutiones Physiologicæ.* Amstelod. 1809, 2 vol. 8vo.

PREFACE

TO

THE FIRST EDITION.*

THESE Elements of Physiology, which contain an abstract of the doctrines I have taught for several years past in my public lectures, are written on the model of the small work on Physiology of the great and immortal Haller, (*Primæ Lineæ Physiologiæ*). I am far, however, from presuming to say that I have equalled the merit of a work which, as is remarked by a man of the highest ability,† when it appeared, gave a new aspect to the science, and commanded universal approbation. If these new Elements of Physiology deserve any preference over that work, the honour is not due to the Author, but to the times in which he writes, enriched by the progress of the physical sciences, with a multitude of data and results that may be said to have rendered Physiology altogether a new science.

It will be easily perceived that the plan I have adopted differs essentially from that followed by several respectable physicians: and that the treatises on Physiology, most lately published, resemble the present only in their title. In combining a great number of facts, in adding to those already known the result of my own observation and experience, and in connecting them, by a method that should unite accuracy and simplicity, I have had it in view to keep a due measure between those elementary works whose conciseness approaches to obscurity and dryness, and those in which the authors, omitting no detail and exhausting in a manner their subject, seem to have written only for those who have leisure or inclination for the profoundest study.

Should any conceive that the present undertaking is above the capacity of my age, I will say, even at the risk of a paradox, that young men are perhaps fittest to compose elementary works, because the difficulties they have encountered in the study are yet fresh in their memory, as well as the steps which they have taken to overcome them; and further, because their recent experience points out to them the defects and advantages of the different methods of other instructors:‡ so that he who in the shortest space of time has carried to the greatest extent his own acquisition of sound knowledge, will, in some respects, be the best guide to his successors in the difficult and perplexing paths of elementary study.

In the composition of the work I have borne constantly in mind the necessity of sacrificing elegance to clearness, which I know to be the most important merit of an elementary treatise. Further, I have throughout followed, I believe, the same arrangement in the succession of the subjects, and applied to the science of living man the principle of the association of ideas; a principle so well developed by Condillac, in his Treatise on the Art of Writing, and to which that philosopher has shewn that all the rules of the art are to be referred. Notwithstanding the rigorous law to which I have subjected myself, I have, after the example of the ancients, and, among the moderns, of Bordeu, and of several other physicians and physiologists of equal celebrity, thought myself justified in employing, when I felt it necessary, metaphorical expressions; because, as has been justly observed by a writer who has been, in our own times, an honour to her sex, if conciseness do not consist in the art of reducing the number of words, still less does it consist in depriving language of imagery. The conciseness which is to be envied is that of Tacitus, at once eloquent and

* Published in 1801.

† "When Haller published his *Primæ Lineæ Physiologiæ*, which he valued most of all his works, a considerable sensation was excited in the schools. In works on the same subject, it was customary to find long dissertations, almost always void of proof, extraordinary opinions, or brilliant fictions. It was matter of wonder, that in Haller's work there should be found only numerous facts, precise details, and direct inferences."—VICQ-D'AZYR.

‡ "The best order in which truth can be set forth, is that in which it might naturally have been discovered; for the surest method of instructing others, is to lead them along the path which we ourselves have followed in our own instruction. In this way we shall seem not so much to lay before them our own knowledge, as to set themselves on the search and discovery of unknown truths."—CONDILLAC.

energetic; and, far from any fear that imagery should injure that justly-admired compression of style, figurative expressions are, indeed, those which comprise in fewest words the greatest sum of ideas.*

Those who insist on meeting, in a work on Physiology, with a romance instead of the history of the animal economy, will, no doubt, reproach me with having entirely neglected a great number of hypotheses, ingenious or absurd, on the uses of organs; with having omitted, for example, while speaking of the spleen, to mention the opinion which considers that viscus as the seat of mirth and laughter; with having said nothing of the opinion of those authors who conceive it to maintain, by counterpoising the liver, the equilibrium of the two hypochondria; nor even of the doctrine of the ancients, who ascribed to it the excretion of the atrabilis, &c. To recall such errors for the sake of elaborate refutation, would be wasting much precious time in idle discussions, and possessing, as Bacon calls it, the art of making one question bring forth a thousand, by answers more and more unsatisfactory. I have chosen to forego all such vain parade, from a clear conviction, that works of merit are as often distinguished by some things that are not to be found in them, as by those they do contain.

Several authors, in treating of the science of man, have indulged themselves in frequent excursion into the vast field of accessory sciences, and have, without necessity, incorporated in their works whole chapters on air, on sound, on light, and other subjects which belong to the department of natural philosophy and chemistry. Haller himself is not entirely free from blame, for having discredited Physiology by this borrowed display. I have introduced only such general ideas of the subject as were absolutely necessary to render my own intelligible, and were, indeed, too closely connected with it to admit of separation.

One of the principal faults of writers on Physiology is, that they are apt to fall into frequent repetitions; and that fault is often owing to the difficulty of settling satisfactorily the limits of actions which are mutually connected and dependent among themselves, and running into each other, like those that are carried on in the animal economy.

"In composition, one should avoid prolixity, because it is fatiguing to the mind; digressions, because they divert the attention; frequent divisions and subdivisions, because they are perplexing; and repetitions, because they are oppressive. What has been once said, and in its proper place, is clearer than if several times repeated elsewhere."† In following these precepts, and they cannot be too much attended to, one may, it is true, incur the risk of being thought superficial by superficial readers, who form their opinion of a work from the perusal of a single chapter; but a most ample compensation will be found in the opinion of those who choose to be thoroughly acquainted with a work before they pass on it their final judgment.

After having stated in what spirit this work has been written, I may say something of the motives which have led to its publication. I would mention, in the first place, the advantage which, it might be expected, would accrue to the science, and to those who are engaged in its pursuit; and, in the next place, the satisfaction which study has in store for him who bestows on it the time he can snatch from the laborious practice of our art. In his short intervals of leisure from public instruction and from professional duty, left to himself and his own thoughts, in the silence of study, and in the calm of meditation, he looks down with an eye of pity on those who drag on, through the lowest intrigues, a despicable existence, and finds his consolations against the endless vexations that are prepared for him by supercilious ignorance and jealous mediocrity.

* *De la Littérature, considérée dans ses rapports avec les Institutions Sociales*, par Madame de Stael Holstein, tome ii.

† Condillac, *Essai sur l'Origine des Connoissances Humaines*, seconde partie, sec. ii. chap. iv.

ANALYTICAL TABLE

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APPENDIX,

CONTAINING

ADDITIONAL NOTES AND DISQUISITIONS,

BY THE EDITOR.

ADDITIONAL NOTES

TO THE PRELIMINARY DISCOURSE.

ADDITIONAL NOTES TO THE CHAPTER ON DIGESTION.

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APPENDIX, No. II.

THE CHEMICAL CONSTITUTION OF THE SOLIDS AND FLUIDS OF THE HUMAN BODY.

PRELIMINARY DISCOURSE.

Physiology* is the science of life. The term life is applied to an aggregate of phenomena, which manifest themselves in succession, for a limited time, in organised bodies. Combustion is likewise only a combination of phenomena; oxygen unites with the substance which is burning, caloric is disengaged from it; affinity is the cause of these chemical phenomena, as attraction is the cause of the phenomena of astronomy, and in the same manner as the sensibility and contractility of living and organised bodies are the primary causes of all the phenomena which such bodies exhibit—phenomena which, in their union and aggregate succession, constitute life.

The false notions which have been entertained on the subject of life, and the vague definitions which have been given of it, are to be accounted for, by considering that physiologists, instead of regarding life as a simple result, have mistaken it for the properties of life. These last are causes: the first is merely an effect, more or less complex; and, as the spring of a watch, or rather the elasticity of that spring, determines, by the mere action of the wheels, the motion of the hands, and all the phenomena of which the machine is capable; so the vital properties acting by the organs produce all those effects, which in their combination constitute life.† These effects are more or less numerous, according to the number of the organs: they become more rapid, too, in their succession, and life more active with the increase of energy in the vital properties, precisely as the motions of a watch become more complicated, stronger, or quicker, according to the greater tension of the spring, or the increased number of the wheels. Sensibility and contractility are to be ranked among primary causes, of whose existence and laws we acquire a knowledge from observation, but whose essence eludes our investigation,‡ and will probably remain for ever beyond its reach.

Sect. I.—OF NATURAL BEINGS.

The vast domain of nature is divided between two classes of beings. *Inorganic* beings, possessing merely the common properties of matter; *organic* and *living* beings, obeying particular laws, though subjected to the general laws which regulate the universe. Each of these two grand divisions is naturally divided into two classes: we meet with inorganic bodies under the form of *elementary substances*, simple and not capable of analysis, or else under the form of *mixed* substances, compound, and admitting of decomposition. Thus, too, organised beings exist under two very different forms of life, which distinguish them into vegetables and animals.

* Anatomy is *the science of organization.*

† See Appendix, Note A.

‡ It would be wrong to infer, from our ignorance of the nature of the vital properties, that physiology is an uncertain science. Its certainty, in that point of view, is equal to that of other parts of natural philosophy. The chemist, who explains all his combinations by referring them to the principle of affinity, and the astronomer, who finds in attraction the cause that rules the universe, are absolutely ignorant of the nature of those properties.

The first general conception with which we ought to enter upon this comprehensive study of nature is, the mutual dependence of those beings, which, in their co-ordinate whole, compose the system of nature—a dependence which requires for each the simultaneous existence of all. Thus a vegetable derives its nourishment from inorganic bodies,* and alters their inert substance, which is unfit for the food of animals, unless it has previously undergone the influence of vegetable life.

SECT. II.—OF THE ELEMENTS OF BODIES.

Another consideration, of equal importance with the former, is, the convertibility of all those substances so different from one another, and their capacity of being reduced to a small number of simple substances, called *elements.* The ancient doctrine of Aristotle, relative to the four elements, still prevailed in the schools, with a few modifications which it had received from the chemists, when the "pneumatists"† demonstrated, by their beautiful experiments, that three, at least, of these pretended principles of bodies,—air, water, and earth,—far from being simple substances, were evidently formed by the union and combination of several others; that atmospherical air, for example, far from being a homogeneous fluid, was composed of many different gases, and that in its purest state it contains at least two very distinct principles—oxygen and azote; that water is a compound of oxygen and hydrogen, and that earth contains clay, lime, silex, &c.

We have seen added, in the present day, to the number of the elements or simple substances, several which were not considered as such at the time when our natural philosophers, misled by erroneous metaphysical doctrines, had created out of their imaginations beings of the existence of which they could find no proof. There is every reason to believe, that the number of substances not admitting of decomposition, limited at present to fifty-one, without embracing the imponderable bodies, may hereafter be increased or diminished by the discovery of new principles in simple substances, or of new elements in compound bodies, which have hitherto eluded the investigation of chemists. Whatever may be the success of their inquiries, of which it is impossible to foresee the results or to fix the limits, there is reason to believe that it will ever be denied us to arrive at a knowledge of the true elements of bodies, and that many of those substances, which the imperfection of our means of decomposition or analysis obliges us to consider as such, are frequently compound substances, and subject to their laws.

After what has been stated on the elements or constituent principles of substances, let us now see in what manner the combination of these ele-

* MIRBEL, in his Treatise on Vegetable Anatomy and Physiology, observes, "that plants have the power of deriving nourishment from inorganic matter, which is not the case with animals who feed on animals and vegetables, or on both, but are never nourished on earths, salts, and airs." Richerand has adopted the plausible opinion of Mirbel. Farther inquiry might, however, have shewn them that "earths and salts" furnish as little direct nourishment to plants as to animals. Indeed, it may be observed, that the vegetable kingdom derives the chief part of its food from dead animal and vegetable matters, which, although they contain both "earths and salts," cannot be either ranked under these substances, nor even classed with them.—*J. C.*

† This is the name given to the school of modern chemistry, because it originated from the discoveries made relative to the nature of air and elastic fluids. It must be acknowledged, to the credit of metaphysics, that the old errors were forsaken, only at the period when chemists were thoroughly convinced of this truth, that every idea is obtained through the medium of the senses, and that nothing is to be admitted beyond what they demonstrate in actual experiment.

ments gives existence to all beings, and what are the general differences existing among the great classes into which they are divided.

Sect. III.—DIFFERENCES BETWEEN ORGANISED AND INORGANISED BODIES.

Much attention has been bestowed of late on the difference which exists between organised and inorganised bodies. The latter have been observed to be very different from those which are endowed with life, in the homogeneous nature of their substance, in the complete independence of their molecules, each of which, according to the observation of Kant, has in itself causes to account for its peculiar mode of existence, in that power of resisting decomposition which they owe to the simplicity of their structure, and in the absence of those peculiar powers which free organic bodies from the absolute dominion of physical laws. The multiplicity, the volatility of their elements, the necessary union of fluids and solids, the nutrition and development from the diffusive combination, while the growth of inanimate bodies takes place from the mere juxta-position of particles, the origin of living bodies in generation, their destruction in death,—such are the characters which distinguish organised beings from inorganised substances. We are about to enter into a detail of those characters, to appreciate all their differences; for knowledge is to be acquired only by comparison, and the greater our accuracy in comparing, the more precise and extensive will be the knowledge we obtain. Several modern authors have proved, that it is impossible to obtain an accurate idea of life, except by comparing those bodies which are endowed with it with those in which life has never existed, or has ceased to exist. This comparison, I hope, will be fruitful in interesting results, and will furnish several useful considerations immediately applicable to the knowledge of man.

The first remarkable difference between organised and inorganised bodies is to be found in the homogeneousness of the latter, and the compound nature of the former. Let a block of marble be broken; each piece will be perfectly similar to the rest; there will be no differences among them, but such as relate to size or shape. Break down the fragments; each grain will contain particles of carbonate of lime, which will be throughout the same. On the other hand, the division of a vegetable or an animal shews parts heterogeneous or dissimilar. In different parts there will be found muscles, bones, arteries, blossoms, leaves, bark, pith, &c.

Organised beings cannot live or exist in their natural condition, unless solids and liquids enter at once into their composition. The co-existence of these two elements is necessary; and living bodies always contain a liquid mass more or less considerable, and incessantly agitated by the motion of the solid and living parts. It is, in fact, impossible to conceive life existing without a complicated combination of solids and fluids; and without admitting in the former the faculty of being affected by impressions from the latter, and the power of acting in consequence of those impressions. The water which penetrates into mineral substances does not form a necessary part of them; and one cannot adduce in proof of the existence of liquids in that class of substances, the water of crystallisation, though intimately combined, and rendered solid in the crystallised substances.

These inorganic and homogeneous substances, formed of particles similar to one another, when resolved by decomposition into their last elements, possess a great implicity of inward nature. Among them are ranked all

the substances which do not admit of analysis; the mineral compounds are often binary, as the greater part of saline substances; sometimes they are ternary, but seldom quaternary; while the most simple vegetable contains at least three constituent principles, oxygen, hydrogen, and carbon; and no being possessed of life consists of less than four, oxygen, hydrogen, carbon, and azote. In the degree of composition, nature appears, therefore, to rise in gradations, from the mineral to the vegetable, and from the latter to the animal kingdom. The complicated nature of the latter, the multiplicity of their elements, account for their tendency to alteration. Minerals are not subject to change, unless they are acted upon by external causes. Endowed with a vis inertiæ, they continue in one condition without change. The state of organised bodies is incessantly varying. Their internal parts contain an active laboratory, in which a number of instruments are constantly transforming into their own substance nutritious particles. Besides that tendency to alteration in living animals and vegetables, when deprived of life they become decomposed by a process of fermentation which begins in their internal parts, and by which their nature is changed in proportion to the complication of their structure, and the greater number and volatility of their constituent principles.

All the parts of a living body, whether of an animal or a vegetable, have a natural tendency to a common object, the preservation of the individual and of the species: each of the organs, though provided for a peculiar action, concurs in this object; and life in general, or life properly so called, is the result of that series of concurring and harmonic actions. On the contrary, each part of an inorganic mass is independent of the other parts, to which it is united only by the force or affinity of aggregation. When such a part is separated from the rest, it maintains all its characteristic properties, and differs only by its size from the mass to which it no longer belongs.

Among animals and vegetables, all the individuals of the same class appear to have been formed after the same model; their parts are equal in number, and resemble each other in colour; their differences are slight and evanescent. The forms peculiar to organised beings are, therefore, invariably determined; and when nature departs from them, she never does so to such a degree as in the shapes of minerals. The veins of mines are never precisely alike, as the leaves of vegetables or the limbs of animals. Crystals, formed from similar substances, assume very different shapes, equally distinct and precise. Carbonate of lime, for example, assumes, according to circumstances, the shape of a rhomboid, that of a six-sided regular prism, that of a solid, terminated by twelve scaleni triangles, that of a different dodecahedron with pentagonal faces, &c., as may be seen at large in the writings of Haüy.

A powerful inward cause seems to arrange the constituent parts of animal and vegetable bodies by a determinate rule, in such a manner that they shall present a surface more or less completely rounded. Minerals often take their form from external bodies; and when an especial force assigns it to them, as in crystals, their surfaces are flat and angular. When the crystallisation is disturbed, and the molecules of the crystals are driven tumultuously together, the geometrical form is impaired; the parts are rounded which would have been terminated by angles, if a slow and tranquil crystallisation had allowed of regular aggregation; and, as M. Haüy has remarked, these waving outlines, these roundings, so frequent in vegetables and plants, where they belong to beauty of form, are, in minerals,

indication of defects. True beauty, in these beings, is characterised by the straight line; and it is on good grounds that Romé de Lisle* has said of this sort of line, that it seems to have an especial determination to the mineral kingdom.

Amongst all the characteristics which distinguish the two great divisions of natural bodies, the most absolute and the most palpable is that which is drawn from the manner of growth and of nourishment. Inorganic bodies grow only by accretion, that is, by the accession of new layers to their surface; whilst the organic, in virtue of its vital powers, receives into intimate combination, and is penetrated and pervaded by, the substance it assimilates to itself. In animals and plants, nutrition is the effect of an internal mechanism; their growth is a development from within. In minerals, on the contrary, growth cannot claim the name of development: it goes on externally, by successive addition of new layers; it is the same being, assuming other dimensions, whilst the organic body is renewed in its growth.

Living bodies spring from a germ, which at first was part of another being, from which it detaches itself for the sake of its own development and growth. From the first, they are already aggregates. Inorganic bodies have no germ: they are made up of distinct parts brought together; they have no birth; but a multitude of molecules, collecting into one, compose masses of various bulk and figure.

Organised bodies alone can die; all have a duration, determined by their own nature; and this duration is not, like that of minerals, proportioned to the bulk and density: for if man has not the life of the oak, whose substance much exceeds his in density, neither does he equal the life of many animals, such as fishes, whose flesh is of inferior consistence to his own: and he lives longer than the large quadrupeds, though his bulk is less. The parts, also, of a living body, are developed and strengthened by exercise: a muscle or an organ, instead of being wasted by repeated action, increases in bulk, whilst friction and use destroy inorganised substances. Spontaneous motion is proper to living bodies, but inorganised matter evinces only communicated movements.

Finally, inorganic are essentially distinguished from organic bodies by the want of these peculiar powers or properties of living nature; powers which uphold the equilibrium of the whole system of nature, as I shall explain more at large when I have considered the differences that mark the two divisions of the organic kingdom, vegetables and animals.

Sect. IV.—DIFFERENCES BETWEEN VEGETABLES AND ANIMALS.

These are much fewer, less absolute, and therefore more difficult to establish. There is, in fact, very little difference between a zoophyte and a plant; and there is a much wider distance in their internal economy, between man, who stands at the height of the animal scale, and the polypus on its lowest line, than between the polypus and a plant. There lies between organised and inorganic bodies a space, which is not to be filled up by figured stones, nor by lithophytes, nor by crystals, in which some naturalists have thought they saw a beginning of organisation: whilst, at the extremity of the animal chain, are found beings, fixed, like plants, on the spot of their birth, sensitive and contractile, like the sensitive and some

* Cristallographie, tom. i. p. 94.

other plants, and reproduced like them from slips. Yet we are able to state some differences sufficiently marked, to assign to the vegetable kind a character of their own, which will not suit the individuals of either of the other kingdoms.

Their nature, more complex than that of minerals, is less so than that of animals: the proportion of the solids to the liquids is greater than in these last: accordingly they retain, long after death, their form and bulk, only that they grow lighter. The solids are, in man, nearly a sixth of the whole body: his carcass, decomposed by putrefaction, remains a little earth, and a light skeleton, when the ground and the air have drawn from it all its juices. A tree, on the contrary, is more than three parts of its substance solid wood. It has been dead for ages; and yet in our buildings it preserves its form and size, though, by drying, it has lost a little of its weight.

Their constituent principles, as they are less in number, are also less diffusable. In fact, azote, which is predominant in animal substances, is a gaseous and volatile principle; whilst carbon, the base of vegetable substance, is fixed and solid. This circumstance, added to the smaller quantity of their liquids, explains the long duration, after death, of vegetable substances.

But of all the characteristics which have been employed in establishing the limits of animal and vegetable nature, there is one quite sufficient to distinguish these two great classes of beings; but which has not been allowed the weight it deserves.

The zoophyte, who, fixed in his rocky habitation, cannot change his place, confined to partial movements, which certain plants are possessed of, who, besides, has not that sensitive unity so remarkable in man, and in the animals who nearest resemble him in their organisation; the zoophyte, whose name indicates an animal plant, is totally separated from all beings of the vegetable kingdom, by the existence of a cavity, in which alimentary digestion is carried on,—a cavity, by the surface of which is an absorption, an *imbibition*, far more active than that which takes place by the external surface of the body. From this shapeless animal, up to man, nutrition is effected by two surfaces, and especially the internal; whilst in the plant, nutrition, or rather the absorption of nutritive principles, is only by the external surface.*

Every animal may be considered, in extreme abstraction, as a nutritive tube, open at the extremities;† the whole existence of the polypus seems reduced to the act of nutrition, as its whole substance is employed in the formation of an alimentary tube, of which the soft parietes, extremely sensible and contractile, are busied in appropriating to themselves, by a sort of absorption, the substances which are brought into it. From the worm up to man, the alimentary canal is a long tube, open at the extremities; at first only of the length of the body of the animal, not bent at all in passing from the head to the tail, and carried on towards the mouth, and towards the anus, with the external covering of the body; but soon re-

* This most prominent characteristic of animal organisation was first pointed out by Boërhaave; and afterwards insisted on by Dr. Alston of Edinburgh; and recently by Dr. A. T. Thomson, in his excellent work on the Elements of Botany.—*J. C.*

† *Lacepède,* Histoire Naturelle des Poissons, tom. i. There may be brought against this principle, the instance of some zoophytes, such as sponges, &c.; but do these bodies really belong to the animal kingdom? and should not we be warranted in rejecting them, by the want of the alimentary cavity, the essential characteristic of animal existence?

turning upon itself, and stretching out into length far beyond that of the body which contains it.

It is in the thickness of the parietes of this animated tube, betwixt the mucous membrane that lines it inwardly, and the skin with which this membrane is continuous, that all the organs are placed, which serve for the transmission and elaboration of fluids, together with the nerves, the muscles, in short, all that serves for the carrying on of life. As we rise from the white-blooded animals to the red and cold-blooded, from these to the warm-blooded, and from these to man, we see a progressive multiplication of the organs that are contained within the thickness of the parietes of the canal:—if we follow, on the other hand, the descending scale, we see this structure gradually simplified, till we arrive at last at the polypus, and find in it only the essential part of animal existence. The simplicity of its organisation is such, that it may be turned inside out, and the external be made the internal surface; the phenomena of nutrition, which are the whole life of the animal, go on, from the close analogy between the two surfaces; unlike to man and the greater part of animals, in whom the skin and the mucous membranes, though growing into each other, though linked by close sympathies, are far from possessing a complete analogy of structure, or a capacity for the interchange of functions.

Man, then, and the whole animal kind, carry about within themselves the supply of their subsistence; and absorption, by an inward surface, is their distinguishing characteristic. It is inaccurate to ascribe to Boërhaave the comparison of the digestive system of animals to the soil in which plants suck up the juices that feed them, and the chylous vessels to real internal roots. I find the same thought well expressed in the work on humours, which, justly or falsely, bears the name of Hippocrates: *Quemadmodum terra arboribus, ita animalibus ventriculus.*

The digestive tube, that essential part of every animal, is the part of which the existence and action are the most independent of the concurrence of the other organs, and to which the properties of life seem to adhere, if one may say so, with most force, Haller,* who has made so many and such interesting inquiries into the contractile power of the muscular organs, examining them under the twofold relation of their irritability, as it is more or less lively, or more or less lasting, looks on the heart as the one in which these two conditions are found in the highest combination. He gives the second place to the intestines, the stomach, the bladder, the uterus, and the diaphragm; and, after these, all the muscles under the command of the will. I had at first admitted, with every other writer, this classification of the contractile parts; but more than a hundred experiments on living animals have satisfied me that the intestines are always the last part in which the traces of life may be discovered. Whatever may be the sort of death by which they are destroyed, peristaltic motions, undulations, are still continued in this canal, while the heart has already ceased to beat, and the rest of the body is all an inanimate mass. M. Jurine has already observed on the pulex monoculus, that, of all the parts of the body of this little white-blooded animal, the intestines were the last to die.†

* *Opera Minora*, 3 vols. 4to.

† If the intestinal tube be the *ultimum moriens*, if it be the last organ in which life lingers and goes out, it is to it we ought to direct, in preference, the stimulants that are capable of recalling it in case of asphyxia. After the blowing of pure air into the lungs, the means that ought next to be attended to is the injection of acrid and irritating clysters thrown in with force. The large intestines are connected with the diaphragm by a close sympathy, as is proved by the phenomena of fœcal eva-

Sect. V.—OF LIFE.*

After having thus laid down, between organic bodies and organised living beings, and again between animal and vegetable nature, a line of demarcation that cannot be mistaken, let us endeavour to exalt ourselves to the conception of Life; and, for accuracy of thought, let us, in some sort, analyse it, by studying it in all the beings of nature that are endowed with it. In this study, of which I may be allowed to state, in advance, the results, we shall see life composed at first of a small number of phenomena, simple as the apparatus to which it is given in charge; but soon extending itself as its organs or instruments are multiplied, and as the whole organic machine becomes more complex; the properties which characterise it and bear witness of its presence, at first obscure, becoming more and more manifest, increasing in number as in development and energy; the field of existence enlarging, as from the lower beings we re-ascend to man, who, of all, is the most perfect: and observe, that by this time of perfection, it is simply meant that the living beings to which we apply it, possessed of more means, present also more numerous results, and multiply the acts of their existence: for in this wonderful order of the universe every being is perfect in itself, each being is constructed most favourably for the purpose it is to fulfil; and all is equally admirable, in living and animated nature, from the lowest vegetation to the sublimity of thought.

What does this plant present to us that springs up, and grows, and dies every year? A being whose existence is limited to the phenomena of nutrition and reproduction: a machine constructed of a multitude of vessels, straight or winding capillary tubes, through which the sap is filtrated, and other juices necessary to vegetation; these vegetable liquors ascend, generally, from the roots, where their materials are taken in, to the summit, where what remains from nutrition is evaporated by the leaves, and what the plant could not assimilate to itself is thrown off in transudation. Two properties direct the action of this small number of functions: a latent and faint sensibility, in virtue of which each vessel, every part of the plant, is affected in its own way by the fluids with which it is in contact: a contractility as little apparent, though the results prove irrefragably its existence; a contractility, in virtue of which the vessels, sensible to the impression of liquids, close or dilate themselves, to effect their transmission and elaboration. The organs allotted to reproduction animate, for a moment, this exhibition: more sensible, more irritable, they are visibly in action: the stamina or male organs bow themselves over the female organ, the pistils, shake on the stigma their fertilising dust, then straighten, retire from it, and die with the flower, which is succeeded by the seed or fruit.

This plant, divided into many parts, which are set in the earth with suitable precautions, is reproduced and multiplied by slips, which proves that these parts are little enough dependent on each other; that each of them contains the set of organs necessary to life, and can exist alone. The different parts of a plant can live separately, because life in its simpler organs and properties is diffused more equably, more uniformly, than in animals like man, and its phenomena are connected in a less strict and absolute de-

cuation: the irritation of them is the surest means of accelerating it; and this irritation is the easier, as the alimentary canal is the last part that is forsaken by life.

* See Appendix, Note A.

pendence. I myself have witnessed a very curious fact, which confirms what I have said.* A vine, trained against the eastern wall of a forge, shot into the building a few branches. These branches, which entered by straight enough passages, were covered with leaves in the middle of the hardest winters; and this premature but partial vegetation went through all its periods, and was already in flower when the part that remained without was beginning to bud with the spring.

If we pass from the plant to the polypus, which forms the last link of the animal chain, we find a tube of soft substance, sensible and contractile in all its parts, a life and an organisation at least as simple as that of the plant. The vessels which carry the liquids, the contractile fibres, the *tracheæ* which give access to the atmospheric air, are no longer distinctly to be traced in this almost homogeneous substance. There is no organ especially allotted to the reproduction of the kind. Moisture oozes from the internal surface of the tube, softens and digests the aliments which it finds there; the whole mass draws in nourishment from it; the tube then spontaneously contracts, and casts out the residue of digestion. The mutual independence of parts is absolute and perfect: cut the creature into many pieces, it is reproduced in every piece; for each becomes a new polypus, organised and living, like that to which it originally belonged. These *gemmiparous* animals enjoy, in a higher degree than plants, the faculties of feeling and of self-motion; their substance dilates, and lengthens, and contracts, according to the impressions they receive. Nevertheless, these spontaneous movements do not suppose, any more than those of the mimosa, the existence of reflection and will; like those of a muscle detached from the thigh of a frog and exposed to galvanic excitation, they spring from an impression which does not extend beyond the part that feels it, and in which sensibility and contractility are blended and lost in each other.

From this first degree of the animal scale, let us now ascend to worms. We have no longer a mere animated pulp shaped into an alimentary tube: parcels of contractile or muscular fibres; a vessel divided by several constrictions into a series of vesicles, which empty themselves into one another by a movement of contraction that begins from the head, or the entrance of the alimentary canal, and proceeds towards the tail, which answers to the anus; a vessel from which, in all probability, are sent out lateral ramifications; a spinal marrow† equally knotted, or composed of a

* Vegetable life compared in its means and in its results to the life of animals, would throw the greatest light on many phenomena which it is still difficult for us to conceive and to explain. The treatment of disease in plants, for which as much would be gained by these inquiries, is almost entirely surgical. When, to make vegetation more fruitful, the gardener prunes a luxuriant branch; when the peasants of the Cervennes, as M. Chaptal has observed, burn the inside of their chestnut trees to stop the progress of a destructive caries; when the actual cautery is applied to the really ichorous and foul ulcers of many trees, &c., it is to the organs of inward life (or that which carries on the process of assimilation), the only life of vegetables, that surgery is applied; while, on the contrary, in man and animals, it is to the derangement of the external organs that the remedy is directed. I shall conclude this note with an observation on the wounds of plants. Like those of the human body, they are much less dangerous when their surface is smooth than when their edges are hacked, torn, or bruised. Trees felled with the saw will hardly shoot up from the stool, which always furnishes a better growth when an axe has been employed. The saw lacerates the vegetable texture; and its violent and distressing action on the fibres, extending towards the roots, affects, more or less, the organisation The uneven surface of a tree felled in this manner holds wet, as injurious to the trunk, which it rots, as a too great quantity of pus, which bathes constantly the surface of a wound, checks the process of granulation, and resists cicatrisation.

† This class of animals cannot be considered to possess a spinal marrow. The series of ganglions which they exhibit is merely the vertebral ganglia of the sympathetic nerve.—*J. C.*

chain of ganglions,* stigmas, and trachea, analogous to the respiratory organs of plants, and, in some, even gills: all shews clearly an organisation further advanced, and more perfect: sensibility and contractility are more distinct; the motions are no longer absolutely automatic; there are some which seem to suppose choice. The worm, too, may be divided into many pieces; each will become a separate and perfect worm, a head and tail growing to each;† but this division has its term, beyond which there is no longer complete regeneration. It cannot, therefore, be pushed so far as in the polypi. The substance of the worm being formed of elements more dissimilar, it may be that too small a portion does not contain all that is necessary to constitute the animal.

The crustaceous tribes, and among them the lobster, discover a more complex apparatus of organisation. Here you will find distinct muscles, an external articulated skeleton, of which the separate parts are movable upon each other, distinct nerves, a spinal marrow with bulgings, but, above all, a brain and a heart. These two organs, though imperfect, assign the animal to an order much above that of worms. The first becomes the seat of a sort of intelligence; and the lobster acts evidently under impulses of will, when, attracted by a smell, it pursues a distant prey, or when it flies a danger discovered to it by its eyes. There are viscera accompanying the intestinal tube, which give out to it liquids that concur in alimentary digestion. Sensibility and contractility present each two shades: in fact, the parts of the animal are obedient to the internal stimuli, feel the impression of fluids, and contract to impel them; on the other hand, by its nerves and locomotive muscles, the lobster places itself in connexion with the objects that surround it. The phenomena of life are linked together by a strict necessity: it is no longer possible to separate the creature into two parts, of which each may continue to live: there are but few parts you may cut off without injury, while you spare the central foci of life. So, if you take off a claw, you observe soon a little granulation, which swells and is developed, and which, soft at first, is soon clothed in a calcareous covering like that which encloses the rest of its body. This partial regeneration is frequently to be seen.

If from white-blooded animals we go on to the red and cold-blooded, such as fishes and reptiles, we see this power of reproduction becoming more and more limited, and life more involved in organisation. In fact, if you cut off a part of the body of a fish, the tail of a serpent, or the foot of a frog, the separated parts are either not supplied at all, or very imperfectly reproduced. All these creatures maintain, with the medium in which they live, relations of more strict dependence. Gills in these, lungs in others, are added to a heart, nor are less essential to life. However, the action of these chief organs is not so frequent, nor of momentary necessity for the continuance of life. The serpent passes long winters, torpid with cold, in holes where he has no air, without breathing, without any motion of life, and in all appearance dead. These creatures, like all reptiles, are able to breathe only at long intervals, and to suspend, for a time, the admission of air, without risking their existence. Here, the vital powers are distinct and strong, and differ from those of the more perfect animals, and of man, by very slight shades: the heart and the vessels of the fish feel and act within him without his consciousness. Further, he has senses, nerves, and a

* Appendix, Note B.

† This may be observed in several of the intestinal worms. It ought to be kept in recollection during our endeavours to remove them from the body.

brain, from which he has intimation of whatever can affect him ; muscles and hard parts, by the action of which he moves and changes his place, adapting himself to the relations that subsist between the substances around him and his own peculiar mode of existence.

We are come, at last, to the red and warm-blooded animals, at the head of which are the mammiferæ and man. They are entirely alike, save some slight differences in the less essential organs. There is none that has not the vertebral column, four limbs, a brain which fills exactly the cavity of the skull, a spinal marrow, nerves of two sorts, five senses, muscles partly obedient to the will, partly independent in their action : add to these, a long digestive tube coiled upon itself, furnished at its mouth with agents of saliva and mastication ; vessels and lymphatic glands, arteries and veins, a heart with two auricles and two ventricles, lobular lungs, which must act incessantly in impregnating the blood that passes through them with the vital part of the atmosphere,* if which fail, life is suspended or gone. None of their organs live but while they partake in the general action of the system, and while they are under the influence of the heart : all die, irrecoverably, when they are parted from the body of the animal, and are in no way replaced, whatever some physiologists may have said on pretended regeneration of the nerves and some other parts.

Every thing that is important to life is to be found in these animals; and as the most essential organs are within, and concealed in deep cavities, a celebrated naturalist was correct in saying, that all animals are essentially the same, and that their differences are in their external parts, and chiefly to be observed in their coverings and in their extremities.

The human body, consisting of a collection of liquids and solids, contains of the former about five-sixths of its weight. This proportion of the liquids to the solids, may, at first sight, appear to you beyond the truth : but consider the excessive decrease of size of a dried limb ; the gluteus maximus, for example, becomes, by drying, no thicker than a sheet of paper. The liquids, which constitute the greatest weight of the body, exist before the solids ; for the embryo, which is at first in a gelatinous state, may be considered as fluid : besides, it is from a liquid that all the organs receive their nourishment and repair their wastes. The solids, formed from the liquids, return to their former state, when, having for a sufficient length of time formed a part of the animal, they become decomposed by the nutritive process. Even from this slight view of the subject, fluidity is seen to be essential to living matter, since the solids are uniformly formed from the fluids, and eventually return to their former state. Solidity is, then, only a transient condition and an accidental state of organised and living matter ; and this circumstance affords to the humoral pathologists ample opportunities of embarrassing their opponents with many objections not easily answered.

The simplest living bodies, as the infusoria, polypi, &c. are only found in water ; so that we may justly say, with M. Lamarck, that it is exclusively in this fluid that the animal kingdom has derived its origin. Water forms the principal part, and the principal vehicle of all the animal fluids ; it contains saline substances in a state of solution, and even animal matter itself is found in it fluid, and that in three different conditions, under the form of *gelatine*, of *albumine*, or *fibrine*. The first of these substances, solidified, forms the basis of all the organs of a white colour, to which the ancients gave the name of spermatic organs, such as the tendons, the aponeurosis, the cellular tissue, and the membranes. Albumine exists in abundance in

* See Chapter on Respiration.

almost all the humours: the fibrine of the blood is the cement which is employed in repairing the waste of a system of organs, which, in point of bulk, hold the first rank among the constituent parts of the human body—I mean the muscular system. The chemists suspect, and not without reason, that the animal matter passes successively through the different states of gelatine, albumine, and fibrine; that these different changes depend upon the progressive animalisation of the animal matter, which is at first gelatinous, a hydro-carbonous oxyde, containing no azote, and acidifiable by fermentation, becomes more closely combined with oxygen, takes up azote, so as to become albumen, capable of putrefaction; and finally is converted into fibrine by a super-addition of the same principles.

The solid parts are formed into different systems, to each of which is intrusted the exercise of a function of a certain degree of importance. Limiting the term organic apparatus, or system, to a combination of parts which concur in the same uses, we reckon ten, viz. the *digestive* apparatus, consisting essentially of the canal which extends from the mouth to the anus; the *absorbent*, or lymphatic system which is formed of the vessels or glands of that name; the *circulatory* system, which consists of an union of the heart, the veins, the arteries, and the capillary vessels; the *respiratory*, or pulmonary system; the glandular, or *secretory* system; the *sensitive* system, including the organs of sense, the brain, and spinal marrow; the *muscular* system, or that of motion, including not only the muscles, but their tendons and aponeuroses; the *osseous* system, including the appendages of the bones, the cartilages, the ligaments, and the synovial capsules; the *vocal* system; and the *sexual* or *generative* system, different in the two sexes. Each of these organic systems contains in its structure several simple tissues, or "similar parts," as the ancients called them. These tissues, in man, may be enumerated as follow: *cellular tissue*, *nervous tissue*, *muscular tissue*, besides that *horny substance* which constitutes the basis of the epidermis, the nails, and the hair.*

These four substances may be considered as real organic elements, since, with our means of analysis, we never can succeed in converting any one of these substances into another. The cerebral pulp is not convertible into a horny substance, into cellular substance, or into muscular fibre; neither can any one of these tissues ever be converted into cerebral pulp. The bones, the cartilages, the ligaments, the tendons, the aponeuroses, may, by

* One of the oldest divisions of the *primary textures* of the body, and one which nearly coincides with that given by the author, acknowledges three tissues only, viz. the *cellular*, *nervous*, and *muscular*. This arrangement has been adopted by the majority of physiologists since the time of Haller. It may be shewn, that all the textures and organs of the body result either from the various distribution of these primary tissues, or from the cellular only, in consequence of a greater condensation of its substance, or approximation of the molecules of matter entering into its constitution, and owing to a deposition of earthy substance between its interstices, as in the bones. It may, however, be a matter of doubt, whether the muscular texture does not arise from the union of the cellular tissue with the nervous substance; the former combining with the fibrilæ of the organic or ganglial nerves to form the muscular fibres generally, whether involuntary or voluntary; while the latter class of muscular fibres derive their peculiar characters and functions from the accession of the fibrilæ of voluntary nerves to the ganglial and cellular textures. If this position be allowed, the involuntary muscular fibres will appear to result from the combination of the cellular substance with the ganglial nerves only; the voluntary, from the union of the cellular with both the ganglial and cerebral matters composing the extremities of their ramifications, the muscular fibre varying its character and phenomena according as more or less of either kind of nervous substance enters into its composition. An intimate view of the mode of distribution which characterises both classes of nerves, as well as various other considerations, support this opinion, which is calculated to form the basis of plausible explanations of many of the most important appearances and functions of the different kinds of muscular texture.—*J. C.*

long maceration, be converted into cellular substance. Muscular fibres are not subject to that alteration, nor is the nervous or cerebral pulp: the horny substance also resists that change. Every thing, therefore, leads us to acknowledge these four constituent principles in our organs.

The primitive or simple tissues, variously modified and combined in different quantities and in various proportions, constitute the substance of our organs. Their number is much more considerable, according to Bichât, whose happiest conception was this analysis of the human organisation. This physiologist reckoned in the human economy no fewer than twenty-one general or generating tissues.* But it is evident that this analysis is carried too far; that the tissues of which the skin and the hair are formed are exactly of the same nature, are analogous in their properties, and are nourished in a similar manner; that the cellular tissue is the common basis of the osseous, cartilaginous, mucous, serous, synovial, dermoid, &c.

It must be confessed, that this separate consideration of each organic tissue has furnished him with new ideas, ingenious analogies, and useful results; and that his "Anatomie Générale," in which those researches are contained, is his chief title to glory. That glory would be complete, if, in that book, and yet more in his other works, he had done his predecessors, as well as his contemporaries, the justice they had a right to expect from him.

The simple or elementary fibre, about which so much has been written, may be considered as the philosopher's stone of physiologists.† In vain has Haller himself, in his pursuit of his chimera, told us, that the elementary fibre is to the physiologist what the line is to the geometer, and that, as all figures are formed from the latter, so are all the tissues formed from this fibre. *Fibra enim physiologo id est quod linea geometræ, ex quâ nempè figuræ omnes oriuntur.* The mathematical line is imaginary, and a mere abstraction of the mind; while the elementary fibre is allowed a material or physical existence. Nothing, therefore, can make us admit the exist-

* The following classification of the primary and compound textures nearly coincides with that recommended by Dupuytren and Magendie:—

Systems of Textures.

1. Cellular.
2. Nervous . . . . { Ganglial, Cerebral.
3. Muscular . . . . { Involuntary, Voluntary.
4. Vascular . . . . { Arterial, Venous, Lymphatic.
5. Osseous.
6. Fibrous . . . . { Fibrous, Fibro-Cartilaginous, Dermoid.
7. Erectile.
8. Mucous.
9. Serous.
10. Synovial.
11. Glandular.
12. Epidermous, or Corneous.—*J. C.*

† Almost every physiologist who has written on animal organisation has proposed a new arrangement of the *primary textures.* We will only take notice of the two following:—WALTHER considered the different organs and compound textures to result from the *cellular* or *membranous*, the *vascular* or *fibrous*, and from the *nervous*. J. F. MECKEL founds his classification of organic substances on microscopic researches. He is of opinion that the solids and fluids of the human body can be reduced to *two elementary substances*, the one formed by globules, the other by a coagulable matter which, either alone or united to the former, constitutes the living fluids, if it be in the liquid state, and gives rise to the solid tissues, when it assumes the concrete form. See APPENDIX, Note C, for a more detailed account of the opinion of this eminent anatomist.—*J. C.*

ence of a simple, elementary, or primitive fibre, since our senses shew us, in the human organisation, four very distinct materials.

Each of these four substances, of which our solids are formed, and the principles of which, as we have seen above, are contained in the fluids, may be chemically resolved into azote, oxygen, hydrogen, and carbon. To these four chemical elements of our textures may be added phosphorus, sulphur, lime, iron, and some other substances which are not so constantly present in the fluids and solids as those enumerated. Shall we also mention, as constituents of the animal economy, certain substances which are not subjected to the laws which ponderable bodies evince, and which are made known to us chiefly by their effects, such as caloric, light, and electricity, of which magnetism and galvanism are the effects?

Among the organs, whether single or combined in systems, which enter into the human organisation, there are some whose action is so essential to life, that with the cessation of that action life at once becomes extinct. These primary systems, whose action regulates that of all secondary systems, are as numerous in man as in the other warm-blooded animals. None of them can act unless the heart sends into the brain a certain quantity of blood, vivified by the contact of atmospherical air in the pulmonary tissue. Every serious wound of the brain or heart, every lasting interruption to the access of blood into the former of these organs, is invariably attended with death. The oxydation of the blood, and its distribution into all the organs, is consequently the principal phenomenon on which the life of man and of the most perfect beings depends.

Sect. VI.—OF THE VITAL PROPERTIES; SENSIBILITY AND CONTRACTILITY.*

By sensibility is meant that faculty of living organs which renders them capable of receiving, from the contact of other bodies, an impression, stronger or fainter, that alters the order of their motions, increases or diminishes their activity, suspends or directs them. Contractility is that other property by which parts excited, that is, in which sensibility has been called into action, contract or dilate; in a word, act and execute motions. In the same manner, as we have not always a consciousness of the impressions received by our organs, and as, for example, no sensation informs us of the stimulating impression by which the blood calls the heart into action; so it is by reflection only that we are induced to admit the existence of certain motions; of those, for instance, by which the humours, when they have reached the smallest vessels, become incorporated into the tissue of our organs.† These motions, to make use of an ingenious comparison, resemble those of the hour-hand compared with the second-hand of a watch. The hour-hand appears motionless, and yet in twelve hours it describes the whole circumference of the dial-plate, round which the other hand moves in one minute, with a motion that is visible.

In considering life through the great series of beings that possess it, we have seen that those in which it is most limited, or rather, in which it consists of the least number of actions and phenomena,—vegetables, for instance, and animals like the polypus, which have no brain, no distinct nervous system,—are at once endowed with sensibility and contractility in all

* See Appendix, Note D.

† If the suggestions offered in the note at p. 12, respecting the constitution of the different kinds of muscular fibres, were adopted, the explanation of the properties, sensibility and contractility, and the relations which they hold with the circle of vital functions would be more apparent and better understood.—*J. C.*

their parts. All living beings, all the organs which enter into their composition, are impregnated, if we may be allowed the expression, with these two faculties necessarily co-existing, and which shew themselves by internal and nutritive motions, obscure, indeed, and to be distinguished only by their effects. These two faculties appear to exist in the degree absolutely required for enabling the fluids that pervade all the parts of a living body to induce the action by which these parts are to assimilate such fluids. It is clear that the two properties of feeling and of motion are indispensable to all parts of the body. They are properties universally diffused through organised and living matter; but they exist without possessing any peculiar organ or instrument of action. Were it not for these two faculties, how would the different parts act on the blood, or on the fluid which supplies its place, so as to obtain from it the materials subservient to nutrition, and the different secretions? These faculties are therefore given to every thing that has life — to animals, to vegetables, to man in his waking hours, or in his most profound sleep, to the fœtus, to the child that is born, to the organs of the assimilating functions, and to those which connect us with surrounding beings. Both these faculties, obscure and inseparable, preside over the circulation of the blood, of the fluids, and, in short, over all the phenomena of nutrition.

Though this kind of sensibility is always latent or concealed, it is otherwise with regard to contractility, which may be sensible or otherwise. The bone, which takes up the phosphate of lime, to which it owes its solidity, exerts that action without our being aware of its taking place, except by its effect; but the heart which feels the presence of the blood, without any consciousness on our part of such sensation, exerts motions that are easily perceptible, but over which we have no control, either to suspend or accelerate them.

Vital properties in so weak a degree would not have been sufficient to the existence of man, and of the animals which resemble him,—obliged to keep up multifarious intercourse with every thing that surrounds them; thus they enjoy a very superior kind of sensibility, by means of which the impressions which affect some of their organs are perceived, judged, and compared. This mode of sensibility might be more properly called *perceptibility*, or the faculty of accounting to oneself for the emotions which are experienced. It requires a centre to which the impressions may be referred, and therefore it exists only in the animals which, like man, have a brain, or some organ in its stead; so that the zoophytes and vegetables wanting that organ are equally destitute of this faculty. The polypi, and some plants, as the sensitive, perform, nevertheless, certain spontaneous motions, which seem to indicate the existence of volition, and consequently of perceptibility. But these motions are the result of an impression which does not extend beyond the part in which it is experienced, and in which sensibility and contractility are blended.

The almost latent sensibility of certain parts of the body cannot be absolutely compared to that of vegetables, since those organs, whose sensibility is so imperfect, manifest in disease a *percipient* sensibility, which shews itself by acute pain; and it is even sufficient to change the stimulus to which they are accustomed to determine the occurrence of this phenomenon. Thus the stomach, on the parietes of which the food does not in health produce any perceptible impression, becomes the seat of very distinct sensation, and of dreadful pain, when a small quantity of poisonous matter is introduced into it. In like manner, we are not conscious of the

impressions excited in the parietes of the bladder or rectum by the collection of urine or fœcal substances, except when their contents have become sufficiently irritating by their presence to excite in a certain degree those irritable and sensient cavities, and to transform their obscure into a very distinct sensibility. Is there not reason to suspect, that our unconsciousness in health of the impressions made on our organs by the fluids which they contain, depends on our being accustomed to the sensations which they incessantly excite? so that there remains but a confused perception, which in time disappears; and may we not, under that point of view, compare all these organs to those of sight, hearing, smelling, tasting, and touching, that are no longer irritable by stimulants, to which they have long been habituated?

Two systems of organs, very different in their uses and in their qualities, enter into the composition of the human body; they are as two living and united machines,—the one, formed by the organs of sense, the nerves, the brain, the muscles, and the bones, serves to maintain its connexion with external objects; the other, destined to internal life, consists in the digestive tube, and the organs of absorption, circulation, respiration, and secretion. The organs of generation in the two sexes form a separate class, which, as far as relates to the vital properties, partakes of the nature of the other two.

By the organs of sense, and the nerves which form a communication between these organs and the brain, we are enabled to perceive, or to feel, the impressions made on us by external objects: the brain, the true seat of that *relative* sensibility, which might very justly be termed *perceptibility, or the perceptive power* (Pott), when excited by these impressions, is able to irradiate into the muscles the principle of motion, and to induce the exertion of their *contractility.* This property, which is under the direction of the will, manifests itself by the sudden decurtation of a muscle, which swells, hardens, and determines the motion of those parts of the skeleton to which it is attached. The nerves and the brain are essentially the organs of these two properties; a division of the former is attended with a loss of sentiment and voluntary motion in the parts to which they are distributed. The other kind of sensibility is, on the contrary, quite independent of the presence of nerves; it exists in all organs, although all do not receive nervous filaments. It might even be asserted, that the cerebral nerves are not at all essential to the life of nutrition; the bones, the arteries, the cartilages, and several other tissues, in which no nerves are seen to enter, are nourished equally well with the organs in which they exist in considerable number; the muscles themselves will carry on their own internal economy, notwithstanding the division of their nerves; only, deprived of those means of communication with the brain, they can no longer receive from it the principle of voluntary contraction; instead of that sudden, energetic, and lasting decurtation, which the will determines in them, they become merely capable of those quiverings called palpitations.

The anatomist who studies the nerves with a view to ascertain their termination, finds them all arising from the brain and spinal marrow, and proceeding, by a longer or shorter course, to the organs of motion or of sensation: let him take his scalpel and dissect one of our limbs, the thigh, for instance; he will see the cords parting into numerous threads, most of which disappear in the thickness of the muscles; whilst others, after creeping for a time about the cellular tissue, which joins the skin to the aponeurosis, end on the inward surface of the skin, of which they compose the

texture, and expand into sentient papillæ on its surface. The bones, the cartilages, the ligaments, the arteries, and the veins, all those parts whose action is not under the control of the will, are without them.* Nevertheless, all those parts which, in their natural state, send no perceptible impressions to the brain, which, when once insulated, may be tied and cut, without any sign of pain from the animal, and whose action the will does not control, are yet endued with a sensibility and a contractility, which enable them, after their own manner, to feel and to act, to recognise in the fluids that moisten them what is suited to their nourishment, and to separate that recrementitious part which has suitably affected their particular mode of sensibility.†

In confining our attention, then, to the consideration of a single limb, we may easily satisfy ourselves of the existence of two modes of feeling, as of two sorts of motion; a sensibility, in virtue of which certain parts can send up to the brain the impressions they receive, to be there objects of consciousness; and another sensibility belonging to all organs, without exception, and all that some of them possess, which is sufficient for the exercise of the functions of nutrition, and by means of which they are evolved, and are kept up in their natural state; two kinds of contractility, appropriated to the two different kinds of sensibility:—the one, in virtue of which the muscles, obedient to the will, exercise the contractions which it determines; the other, independent of the will, manifests itself by actions, of which we have no intimation, any more than of the impressions by which they are determined.

The distinction being fairly laid down between sensibility and contractility, it is easy to understand the origin of the endless disputes of Haller and his followers, about the parts of the body, in man and animals, which are endowed with sensibility and irritability.‡ All the organs to which that learned physiologist has denied these properties, as bones, tendons, membranes, cartilages, and cellular membranes, &c. possess only that latent sensibility, and that obscure contractility, common to all living beings, and without which it is impossible to conceive life to exist. In a state of health, they are utterly incapable of transmitting to the brain perceptible impressions, and of receiving from it the principle of manifest and sensible motion. It has likewise been a matter of much dispute, whether sensibility and contractility are qualities of nerves, if these parts are their only instruments, and if their destruction is attended with a loss of these two vital properties in the parts to which they are transmitted. We may answer in the affirmative, as far as relates to the sensibility of perception and the voluntary motion which is entirely subservient to it; but that the existence of nerves is not at all necessary to the exercise of the sensibility and contractility which are indispensable to the assimilation of nutrition.

* Are destitute, or at least nearly so, of voluntary nerves.—*J. C.*

† All these parts may be considered to possess ganglial nerves; for as these nerves may be demonstrated on the more considerable trunks of arteries, even in the extremities, they may be supposed to accompany these vessels to their most minute ramifications and extremities, and to bestow on them those manifestations which these parts of the vascular system evince. Such, then, being the constitution and connexion of the arterial and capillary vessels, no texture which possesses these vessels can be considered to be destitute of this class of nerves. Those nerves that belong to the other class, the cerebro-spinal, may be inferred to exist in an organ more or less abundantly, or to be entirely absent from it, according to the nature of the phenomena which that organ presents. See the CHAPTERS ON THE CIRCULATION, SENSATION, AND MOTION.—*J. C.*

‡ If the constitution of the muscular fibre, as formerly alluded to, be considered maturely, the source of irritability, and its various degrees of intensity, with the relation which it holds to sensibility, and the other modes of action which the animal textures evince, will become more apparent.—*J. C.*

No part of the living body is absolutely insensible, but that sensibility of every organ is so modified that it is not affected by the same stimuli. Thus, the eye is insensible to sound, and the ear to light. A solution of tartar emetic causes no disagreeable impression to the conjunctiva; taken into the stomach, it excites convulsive motions; while an acid from which the stomach does not suffer, proves a cause of irritation to the conjunctiva, and brings on a violent inflammation of the eye. In the same manner, purgatives pass along the stomach without producing any effect on that viscus, but they stimulate the alimentary canal. Cantharides have a specific action on the bladder, and mercury on the salivary glands. Each part feels, lives, moves, after its own way; in each, the vital properties appear under such shades and modifications, that they may be looked upon as so many separate members of the same family, concurring in one endeavour, working for a common end, *consentientia omnia*. (Hipp.)

The faculty of assigning a cause to the sensations, and that of moving by volition, which man possesses in common with all animals formed with a distinct nervous centre, are essentially bound together. For, suppose a living being, furnished with locomotive organs, but without sensation, placed in the midst of bodies that every moment endanger its existence, without any means of distinguishing them, it will hasten its own destruction. If perceptibility could, on the other hand, exist independently of motion, how dreadful would be the fate of such sentient beings, similar to the fabulous Hamadryads, who, immovably fixed in the trees of our forests, received, without any power to shun them, all the blows inflicted on their rustic abode. Dreams place us sometimes in situations which give us a just idea of their condition. A certain danger threatens our existence; an enormous rock seems to detach itself, to roll and precipitate itself on our frail machine; a frightful monster seems to pursue us, and opens a yawning mouth to ingulf us. We struggle to escape this imaginary danger, to avoid or to repel it; but an irresistible and unknown power, a mighty hand, paralyses our efforts, and keeps us rooted to the spot: it is a situation of horror and despair, and we awaken overwhelmed with the uneasiness which we have suffered.

As there is no part that does not feel in a manner peculiar to itself, so there is no one that does not act, move, or contract, in a manner peculiar to itself; and the parts which have been found without a power of motion analogous to muscular contractility, have remained in that state of immobility only for want of a stimulus fitted to their peculiar nature. Some physiologists say they have excited a distinct quivering in the mesentery of a frog and of a cat, by touching them after they had been previously moistened with alcohol, or muriatic acid.

In the operation for sarcocele,* I have often perceived that, while with my left hand I supported the tumour, and with a scalpel in the right divided the spermatic chord, the tunica vaginalis shewed oscillatory contractions. It visibly contracts in the operation for hydrocele. The injection of an irritating fluid determines evident motions in the tunica vaginalis. The osseous tissue, notwithstanding the phosphate of lime with which it is encrusted, is susceptible of a contraction, whose effects, though slow, are nevertheless undeniable. After teeth have been shed or extracted, the edges

* The contraction of the membrane, formed by the expansion of the cremaster muscle, has doubtless assisted in rendering more distinct the appearance in question. This effect must be particularly distinct at the moment of dividing the spermatic chord. The contractions of the same muscle corrugate the skin of the scrotum when this part is exposed to cold, and draw up the testicles towards the inguinal rings. The contractility of the skin of the scrotum has but little influence in producing this effect.

of the alveolar processes become thinned from contraction, and the alveolar cavities disappear. These facts appear to me to prove, still better than all the experiments performed on living animals (experiments of which, by the by, the results ought not too confidently to be applied to the economy of man), what one should think of the assertions of Haller and his followers, on the insensibility and inirritability of the serous membranes, and of the organs of a structure analogous to theirs.

We shall, at present, say nothing of the porosity, of the divisibility, of the elasticity, and other properties, which are common to living bodies and inanimate substances. These properties are never possessed in their whole extent and in all their purity, if that expression may be allowed. Their results are always influenced by the vital power, which constantly modifies the effects which seem to depend most immediately upon a physical, chemical, or mechanical cause, or upon any other agent whatsoever. When life no longer is present, the organisation is the source of the physical properties exhibited by our organs, and which may be denominated the *properties of the tissues*. It is owing to the organisation that a part exhibits the property of elasticity, and retracts and hardens when submitted to the action of fire. The *extensibility* proceeding from distension, traction, or the application of an analogous force, is dependent upon the organisation, and should not be confounded with the truly vital extensibility which is so manifest in certain organs, as the penis and the clitoris. When excited, they become turgid and dilated by the afflux of humours; but that effect does not depend on a peculiar property distinct from sensibility and contractility. These parts dilate, their tissue stretches under the action of these two properties, which would occasion the same phenomenon in all other parts if their structure were similar.

The same applies to *caloricity*, or that power inherent in all living beings of maintaining the same degree of heat in varying temperatures.* In consequence of which property, the human body preserves its temperature of from thirty to forty degrees (of Reaumur's scale) under the frozen climate of the polar regions, as well as in the burning atmosphere of the torrid zone. It is by the exercise of sensibility and of contractility, that is, by the exercise of the functions over which these vital powers preside, that the body resists the equally destructive influence of excessive heat and cold.

If one were to admit *caloricity* as one of the vital properties, because, according to Professor Chaussier, that power of preserving a uniform warmth is a very remarkable phenomenon, one might be led to suppose a distinct cause or a peculiar property to operate in producing other phenomena of no less importance.

Barthez and Professor Dumas have fallen into the same error; the former, in wishing to establish the existence of a power of permanent situation in the molecules of muscular fibres; the latter, in adding to sensibility and contractility a third property, which he terms the power of vital resistance. Living muscles are torn with much more difficulty than when dead, because the contractility which these organs possess in the highest degree is incessantly tending to preserve the contact of the molecules, the series of which forms the muscular fibre, and even to draw them into closer connexion. This fact, which is brought forward as a proof of the existence of a peculiar power, is easily explained on the principle of contractility.

* See the notes on the subject of animal heat contained in the CHAPTER ON RESPIRATION.

Organised and living bodies resist putrefaction from the very circumstance of their being endowed with life. The continual motion of the fluids, the re-action of the solids on the fluids, the successive and continual renovation of the latter by the reception of new chyle, their constant purification by means of the secretions through which the products animalised in excess are parted with, such are the causes which prevent the putrefactive action from taking place in bodies endowed with life, notwithstanding the multiplicity and the volatility of their elements. Their preservation is therefore a secondary effect, and depending on the exercise of the functions regulated by sensibility and contractility. Nature is distinguished for deriving a multitude of effects from a very small number of causes; it, therefore, shews a very imperfect acquaintance with her laws, to assign a separate cause to each fact.

The separation of the chyle which takes place in the duodenum, from the admixture of the bile with the alimentary substance, the vivification of the blood by respiration, the secretion of the fluids in the conglobate glands, nutrition in the organs, are so many acts of the living economy to which one might feel disposed to assign distinct causes; but these chemico-vital processes are so subordinate to sensibility and contractility, that they are met with only in organs endowed with these two properties, and they take place in a degree more or less perfect according to the condition of these properties in the organs in which they occur.

We have stated that there exist two great modifications of sensibility and contractility; that *sensibility* is divided into percipient *sensibility* and *latent sensibility;* that contractility is at times voluntary, at others *involuntary*, and that the latter may be *perceivable* or *insensible.*

SENSIBILITY.	*Perceiving.* (*Cerebral*, *nervous*, *animal sensibility*, *perceptibility.*) With consciousness of impressions, or *perceptibility;* it requires a peculiar apparatus. *Latent.* (*Nutritive*, *organic sensibility.*) Without consciousness of impressions, or general sensibility, common to every thing that has life; it has no peculiar organ, and is found universally diffused in living parts, animal or vegetable.*
CONTRACTILITY.	*Voluntary and sentient*, subordinate to perceptibility. *Involuntary and insensible*, corresponding to latent sensibility. Tonicity. *Involuntary and sentient.*

The cause of this last modification of contractility appears to depend on the peculiar organisation of the system of the great sympathetic nerves. From these nerves, the heart, the digestive canal, &c. seem to receive the power of exerting sensible contraction; an effect produced by the direct application of a stimulus, and over which volition has no control, as will be stated in speaking of those nerves.

Sensibility and contractility offer a vast number of differences, the principal of which depend on the age, the sex, the regimen, the climate, the state of waking or of sleep, of health or of sickness, on the relative development of the lymphatic, cellular, or adipose systems, and on the proportions which exist between the nervous and muscular systems.

* See Note at page 18.

In the first place, the principle of sensibility and of contractility may in its action be likened to a fluid flowing from any source whatsoever, which is consumed, repaired, and drained by use, re-supplied, or exhausted, equally distributed, or occasionally concentrated on certain organs.

Secondly. Sensibility, like contractility, is very considerable at the instant of birth, and seems to diminish more or less rapidly till death.

Thirdly. The liveliness and frequency of impressions wear it out very early. It, in a manner, repairs itself, that is, recovers its original delicacy, when the sentient organs have been long at rest. Thus, an epicure, whose taste has grown dull with high living, will recover all its accuracy, if, during several months, instead of spiced ragoûts and spirituous liquors, he lives on dry bread and plain water. In like manner, contractility becomes exhausted in the muscles which are too long employed, and it is recovered during the repose of sleep.

Fourthly. The following is an instance of the manner in which sensibility becomes concentrated in one organ, and appears to forsake the others: when the venereal excitement is in its highest degree, animals under its influence receive blows and stings without pain. Domestic animals in that condition are often ill treated, without appearing to feel what is done to them. If the hind legs of the toad are cut off, at the time that he is holding the female firmly embraced, and is pouring his prolific seminal fluid on the ova which are issuing at her anus, he does not lose his hold, he seems insensible to every other sensation; as a man who is taken up with one thought, and absorbed in reflection, is scarcely diverted from it by any means that can be employed. When, during the influence of satyriasis, the vital power is carried to excess in the penis, patients have been known (as we are told by Aëtius) to cut off both their testicles, without suffering the pain usually attending so severe an operation. It is by this law of sensibility that we are to explain the observation of Hippocrates, that two parts of the body cannot be in pain at the same time. If two pains come on at once, the more violent prevents the slighter from being felt. *Duobus doloribus, simul orientibus, non eodem in loco, vehementior obscurat alterum.* In cases of scrofulous swellings, the parts are observed to inflame, to become painful, and suppuration occurs but rarely in every part at once, if the case is serious and attended with acute pain. The germ of a disease, or of a slighter affection, may sometimes remain dormant under a greater pain. I was once overturned in a carriage, from the awkwardness of the coachman, the windows were broken, and my wrists sprained. The right wrist, which had suffered most, swelled first; I employed the proper treatment, and when, at the end of a week, the swelling and pain had almost completely ceased, and the right hand was beginning to recover its suppleness and flexibility, the left wrist swelled, and, in its turn, became pained; two complaints, if they may be called such, appeared in succession, and separately went through their regular course.*

The perfection of one sense is never obtained but at the expense of another; the blind, who bestow more attention on the sensations communicated by the sense of touch and of hearing, often astonish us by the delicacy of these organs; so that, as has been observed, those who, to improve the human voice, have dared to mutilate their fellow-creatures, by depriving them of the organs of generation, might have bethought them-

* John Hunter maintains, from theory, the position that no two different fevers can take place at the same time in the constitution; but that if the two causes of disease exist together, the diseases themselves must be vicarious. And he verifies his reasonings from experience.

selves of putting out their eyes, to render them more sensible to the sweet impressions of harmony.

Fifthly. During sound sleep, the exercise of the percipient faculty, and that of voluntary contractility, are entirely suspended. In that state, it seems as if some covering were thrown over the sentient extremities. We know how hard the hearing becomes, how dull the senses of smell and of taste, how dim the sight, a cloud spreading before the eyes, the moment we are fallen asleep. *Vir quidam, exquisitissimâ sensibilitate prœditus, semiconsopitus coibat; huic, ut si velamento levi glans obductus fuisset, sensus voluptatis referebatur.*

Sixthly. Sensibility is more lively, and more easily excited, in the inhabitants of warm climates than in those of northern regions. What a prodigious difference there is in that respect between the native of Germany and of the southern provinces of France. Travellers tell us, that there are in the neighbourhood of the poles natives so little endowed with sensibility, that they feel no pain from the deepest wounds. The inhabitants of the coast of North America, if we may believe the testimony of Dixon and Vancouver, thrust sharp nails and pieces of glass into the soles of their feet without feeling the slightest uneasiness. On the contrary, the slightest prick from a thorn, for instance, in the foot, is in the strongest African frequently followed by convulsions and locked jaw. The impression of the air is alone sufficient to produce the same accident in the negro children in the colonies, the greater number of whom die of locked jaw a few days after birth.

Montesquieu* very justly observed this difference which exists in the sensibility of the southern and northern nations, and he says of the latter, that "if you would tickle, you must flay them." Now, as the imagination is always proportioned to the sensibility, all the arts that are cultivated and brought to perfection only by the exercise of that faculty, will flourish with difficulty near the icy polar regions, unless the powerful influence of climate be counteracted by well-directed moral and physical causes.

Man is of all beings the one that most powerfully resists the influence of external causes; and although the influence of climate is sufficient to modify his external appearance, so as to lead to a division of the species into several distinct varieties or kinds, this superficial impression is very different from the great alterations to which other beings are exposed from the mere change of climate. Man is every where indigenous, and exists in all climates; while the plants and animals of the equator languish and die when conveyed to the polar regions. From the flexibility of his nature, man enjoys the power of adapting himself to the most opposite situations, of establishing between them and himself relations compatible with the preservation of life. Nevertheless, it is not without difficulty that man undergoes these changes, and accustoms himself to new impressions. The periodical return of the seasons determines that of certain derangements to which the animal economy is subject. The same diseases manifest themselves under the influence of the same temperature, and, to use

* This philosopher has borrowed from the father of physic one of his most brilliant and paradoxical opinions. In his conception, warm climates are the seats of despotism, and the cold, the seat of liberty. This error is completely refuted in the profound and philosophical work of Volney on Egypt and Syria. He shews that what Montesquieu has said of cold climates applies to mountainous regions, while a champaign is more favourable to the establishment of tyranny. Hippocrates had said of the Asiatics, that their being less warlike than the Europeans depended on the difference of climate, and likewise on the despotic form of their government. And he observes, that men who do not enjoy their natural rights, but whose affections are controlled by masters, cannot feel the bold passion of war.—See Chap. XI. on the Varieties of the Human Species.

an ingenious comparison, resemble those birds of passage which visit us at stated seasons of the year. Thus, hemorrhages and eruptive affections come on with the return of the spring; summer comes attended by bilious fevers; autumn brings on a return of dysenteric affections; and winter abounds in inflammations of the lungs and other parts. The influence of climate on the human body does not shew itself merely in occasioning epidemic diseases, the consideration of which leads to the establishing what physicians call *medical constitutions:* this influence operates on man in health, as well as in sickness; and to say nothing of the alterations which our moral nature experiences from the tendency to love, rendered more impetuous with the return of spring, or of the melancholy to which nervous people are often subject towards the end of autumn, when the trees are shedding their leaves, the increase of growth is particularly remarkable at the time of the first growth of plants, as was observed again and again by a friend of mine, physician to a large seminary.

Seventhly. Sensibility is greater in women and children, their nerves* are likewise larger and softer, in proportion to the other parts of the body. In general, the principle of sensibility seems to decrease in proportion as it has contributed to the development of the acts of life; and the power of being impressed by external objects diminishes gradually with age, so that there is a period of decrepid old age at which death appears a necessary consequence of the complete exhaustion of that principle. In short, as I have said in describing the progress of death, at its approach sensibility shews increase of activity and liveliness, as if its quantity required to be completely exhausted before the termination of existence, or as if the organs made a last effort to cling to life.

Eighthly. The development of the cellular and adipose substance diminishes the energy of sensibility; the extremities of the nerves being more covered, and therefore not so immediately applied to the objects, the impressions which are felt are more obscure. The fat operates on the nerves as wool would do on vibrating chords, if wrapped round them, to fix them, to prevent their quiverings, and stop their vibrations.

Very nervous women are very thin; persons of much sensibility have seldom much *embonpoint.* Swine, in which the nerves are covered by a thick layer of fat, are the most insensible of all animals. The susceptibility of the nerves may be diminished, and their sensibility blunted by pressure. The application of a bandage firmly rolled round the body and limbs of an hysterical woman, will diminish the violence of her fits. In dressing wounds affected with what is called the hospital gangrene, I have often relieved the pain by desiring an assistant to apply firm pressure above the sore.

Ninthly. There exists between the force of the muscles and the sensibility of the nerves, between the sensible energy and the force of contraction, a constant opposition, so that the most vigorous athletes, whose muscles are capable of the most prodigious efforts and of the most powerful contractions, are but slightly affected by impressions, and are with difficulty roused into action, as we have explained in giving a history of the nervous and muscular temperaments, which are characterised by this difference. Hence, man has more sensibility than the quadrupeds, although his nerves are smaller than theirs, which seem destined to set the muscles in action, and to serve as nerves of motion rather than of sensation.

There is no muscular fibre, however minute, in which we are not obliged to admit the existence of a small nervous filament, to which it probably

* Their voluntary nerves.

owes the power of contracting. Contractility, at least voluntary contractility, does not appear to be inherent in the muscular fibre, nor independent of the nerves, through the medium of which the will determines the action of the muscles; and if these last organs, when insulated, contract on the direct application of a stimulus, is there not reason to suspect that this stimulus acts on that portion of nerves which remains in the muscle after it has been insulated, and which is intimately united to its fibres? The animals which have no distinct nervous system possess at once in all their parts sensibility and contractility; these two properties become blended in the organs, as well as in the phenomena of life, and can be perceived separate only by a pure abstraction of the mind, which considers in succession the impression produced on these beings, and the motion of their substance, which is an immediate consequence of that impression.*

Sensibility and contractility being always present in living animal bodies, some authors have conceived it more natural to combine them under the common appellation of *excitability*. This one term has been even considered sufficient to designate the whole of the vital properties. But in embracing these properties by this abridged expression, Brown, far from having simplified the study of them, has only increased the obscurity in which they are veiled. In health, as well as in disease, sensibility and contractility do not appear constantly to obey the same laws: action and repose produce not similar effects on them. The sensibility of the eye is enlivened and repaired by the absence of impressions; but a muscle condemned to repose becomes paralytic.

The physiologist who wishes to ascertain the causes of sensibility and contractility is as absurd as the person who endeavours to account for the weight, elasticity, and other secondary properties of matter. These two vital principals are only found in organised bodies: their existence is related to a certain arrangement of parts, which has been conveniently called organisation; but it suffices not that a body should be organised in order that it should enjoy sensibility and contractility—that it should live. Death often supervenes without the organisation having evinced any derangement. A certain commixture or amalgamation of electricity, or of some other imponderable agent, with organised matter, is most probably indispensable to life. But what are the conditions or states of this amalgamation?

We will not enter any farther into a consideration of the laws and phenomena of the vital properties, for fear of being led into useless repetitions when we come to the history of the functions over which they preside. We will conclude what relates to them by presenting the two most important features of their history, I mean *sympathy* and habit.

Sect. VII.—OF SYMPATHY.

There exist among all the parts of the living body intimate relations; all correspond to each other, and carry on a reciprocal intercourse of sensations and affections. These links which unite together all the organs, by establishing a wonderful concurrence and a perfect harmony among all the actions that take place in the animal economy, are known under the name of *sympathies*. The nature of this phenomenon is yet unknown; we know not why, when a part is irritated, another very distant part partakes in that irritation, or even contracts: we do not even understand what are the instruments of sympathy, that is, what are the organs which connect two parts in such a manner, that when one feels or acts the other

* See the notes on *Sensibility* and *Contractility* in Appendix, Note D.

is affected. But though beyond explanation, sympathy is not the less important in the economy of living beings; and these connexions between remote parts constitute one of the most remarkable differences between those beings and inorganic bodies. They are the most characteristic phenomena of vitality. Nothing similar is observable in dead or inanimate nature, in which all things are connected together only by palpable and material links; here the chain is invisible, the connexion evident, the cause occult, and the effect apparent.

Whytt has clearly shewn that the nerves cannot be considered as the exclusive instruments of sympathy,* since several muscles of a limb, which receive filaments from the same nerve, do not sympathise together, while there may be a close and manifest relation between two parts, of which the nerves have no immediate connexion, since each nervous filament having one of its extremities terminating in the brain, the other, in the part to which it is sent, remains distinct from those of the same trunk, and does not communicate with them.

Sympathies may be distinguished into different kinds. In the first place, two organs which execute similar functions:—the kidneys, may supply each other's office. When the uterus is in a state of pregnancy, the breasts participate in its condition, and there is determined into them a flow of humours necessary to the secretion which is to take place. Secondly: the continuity of membranes is a powerful source of sympathy. The presence of worms in the bowels determines an uneasy pruritus around the nostrils. When there is a stone in the bladder, a certain degree of itching is felt at the extremity of the *glans penis*. The secretion of several fluids is determined in the same manner; thus the presence of food in the mouth brings at the extremity of the parotid duct an irritation which extends to the parotid glands, calls them into action, and increases their secretion. Thirdly: if the pituitary membrane is irritated, the diaphragm with which it has no immediate organic connexion, nervous, vascular, or membranous, contracts and occasions sneezing. Is not this sympathy one of those which Haller ascribed to a re-action of the *sensorium commune?* If the impression produced on the olfactory nerves by snuff is too powerful, the uneasy sensation is transmitted to the brain, which determines towards the diaphragm a quantity of the principle of motion sufficient to enable that muscle suddenly to contract the dimensions of the chest, so as to expel a column of air, that may detach from the pituitary membrane the substances that are a cause of uneasiness to it. Fourthly: does not the principle of life seem to control at pleasure the phenomena of sympathy? The rectum, when irritated by the presence of the excrements, contracts; which cause determines the accessory and simultaneous action of the diaphragm and abdominal muscles? Does this connexion depend on organic communications? Why, then, is not the sympathy reciprocal, and why does not the rectum contract when the diaphragm is irritated? Fifthly: can the repeated habit of the same motions explain the harmony which is observed in the symmetrical organs? Why, when our sight is directed to an object placed laterally, does the rectus externus of the eye on that side act at the same time as the rectus externus of the other eye? The indispensable utility of this phenomenon, in keeping a paral-

* The nerves of voluntary motion certainly cannot be supposed to be the instruments of sympathy; but no valid argument can be adduced against the opinion which refers the sympathies to the distribution and connexions of the ganglial class of nerves. See the notes on the chapter which treats of "*the System of the great Sympathetic Nerves.*"—*J. C.*

lelism of the axis of vision, is very obvious; but who can assign the cause? Why are rotatory motions, in different directions, performed with so much difficulty by the arm and leg of the same side of the body? Can it be called a just idea of the innumerable varieties of this phenomenon and of its frequent anomalies, to say, with Rega, that there are sympathies of *action* or of *contractility* (*consensus actionum*), sympathies of *sensibility* (*consensus passionum*).

All these difficulties render it pardonable in Whytt to have considered the soul as the sole cause of sympathy, which was, in fact, a modest avowal of the difficulty of explaining the subject. We are not justified in considering sympathy as an anomalous action, as an aberration of the vital power.* Can it be said that the natural order of sensibility and irritability is inverted in the sympathetic erection of the clitoris and of the nipple, or in the turgescence of the breasts, determined by the gravid state of the uterus?

It is by means of sympathy that all the organs concur in the same end, and yield each other mutual assistance. It affords us the means of explaining how an affection, at first local or limited in its extent, spreads and extends to all the systems; it is thus that every morbid process is carried on. The diseases termed general, always originate, through the medium of association, in the insulated affection of an organ or a system of organs.

In fact, the affections which appear to us most complex in the number, the variety, and the dissimilarity of their symptoms, consist of only one, or of a small number of primitive or essential elements; all the rest are accessory, and depend on numerous sympathies of the affected organ, with the other organs of the animal economy. Thus, if the stomach is the seat of irritation, from foulness of its contents, pains of all kinds come on, but especially in the head and limbs, with a burning heat, nausea, loss of appetite, anxiety; and these symptoms constitute a disease, which appears to affect the whole system.

To go on with the same illustration, the stomach, when oppressed by irritating substances, contracts spontaneously to get rid of them. The universal disturbance which their presence occasions, seems directed towards the same end, as if the suffering organ called upon all the others to assist in relieving it.

These *synergies*, or aggregate motions, tending to one end, and arising out of the laws of sympathy, constitute the diseases termed general, as well as the greater part of those which are called local. It is by means of them, and through these kinds of organic insurrections, if we may be permitted to use this term, which perfectly expresses our meaning, that nature struggles with advantage, and rids herself of the morbific principle, or of the cause of the disease; and the art of exciting and directing these actions furnishes the materials of the most important doctrines of the practice of medicine. I have used the terms excite and direct; for it is

* Sympathy may be considered to be that state of an organ or texture which holds a certain relation to the condition characterising another organ or texture, in health or in disease: or, it may be viewed as a certain relative state of the vital power as it exists in separate organs or textures; as when one part is excited, another participates in the change, and evinces a similar feeling, motion, or function.

Sympathies may be classed into the *reflex* and *direct*. The former may be referred to the cerebral nerves and to the reaction of the sensorium, as when the Schneiderian membrane is irritated, the diaphragm is affected in consequence of the excitement conveyed to the brain, and thence to this muscle by means of its voluntary nerves. The latter class takes place independently of the sensorium, and arises from the ramification and distribution of the ganglial nerves, especially those which are sent to the vascular system. For the elucidation of this subject, see APPENDIX, Note E.—*J. C.*

necessary at times to increase, at others to diminish, their intensity and force, and on some occasions to excite them, when nature, overwhelmed under disease, is almost incapable of reaction. This last circumstance belongs to the diseases of the most dangerous kind, if we include those in which the efforts of nature, though marked by a certain degree of energy, are without connexion or consent, and frustrated by their want of coherence. The character of these affections was first well expressed by Selle, who substituted for the term malignant, which used to be applied to them without any precise meaning, that of *ataxic*, which points out very correctly the want of order, and the irregular succession of their symptoms.*

A knowledge of sympathies is of the highest importance in the practice of medicine.† When we wish to avert an irritation fixed in a diseased organ, experience and observation prove that it is on the organ which bears to it the closest sympathetic connexions that it is useful to apply medicines intended to excite counter-irritation.

This might perhaps be the fittest place to inquire into the nature of those concealed relations which draw men together, and of those aversions which prevent their union; to discover the causes of those secret impulses which lead two beings towards each other, and force them to yield to an irresistible propensity. We might inquire into the reason of antipathy; and, in a word, establish the complete theory of moral sentiments and affections. Such an undertaking is greatly above our strength; and, besides, does not absolutely belong to our subject. It would require a considerable time; and whoever should undertake it, would be in considerable danger of losing his way at every step in the extensive field of conjectures.

Sect. VIII.—OF HABIT.

It is easier to feel the meaning of this term than to define it. Habit, however, may be said to consist in the frequent repetition of certain acts, of certain motions, in which the whole body participates, or only some of its parts. The most remarkable effect of habit is to weaken, after a time, the sensibility of organs.‡ Thus, a catheter introduced along the urethra, and allowed to remain there, causes, during the first day, rather sharp pain; on the second day it feels less uneasy; on the third day it is only troublesome; and on the fourth the patient scarcely feels it. The use of snuff at first increases the secretion of mucus in the nose; but if continued a certain time, it ceases to affect the pituitary membrane, and the secretion would diminish considerably but for the practice of increasing daily the quantity of that acrid powder: the presence of a canula in the nasal duct, after the operation for fistula lachrymalis, increases at first the mucous secretion of that canal; but in proportion as it becomes accustomed to the extraneous body, the secretion returns to its natural condition.

* *Symptomata nervosa, nec inter se, neque causis manifestis respondentia.* Ordo tert. ataxiæ, C. G. Selle. Rudimenta Pyretologiæ Methodicæ.

† This information may be obtained by consulting the works of the ancients, and especially of Hippocrates, who appears to have felt all the importance of this subject. Among the moderns, Vanhelmont, Baglivi, Rega, Whytt, Hunter, Barthez, and Bichât, have collected on this topic a great number of facts obtained from experiments on animals, and especially from observations on diseases.

‡ The influence of *habit* is chiefly perceptible on the organs of sense and voluntary motion.

Habit produces very different effects upon separate parts of the animal economy, according as they are altogether removed from the influence of the will, or as they are more or less, or entirely, subjected to it; the effects of habit, for instance, on our voluntary organs, differ very much from those which result from its operation on the viscera of organic life. See Appendix, Note F.—*J. C.*

It is only by our sensations that we are aware of our existence. Life, to make use of the figurative language of system, of a modern writer, consists in the action of stimuli on the vital powers. (*Tota vita, quanta est, consistit in stimulo et vi vitali.*—Brown.) Sentient beings feel a continual necessity of renewed emotions; all their actions tend to the obtaining agreeable or disagreeable sensations: for, in the absence of other sensations, pain is sometimes attended with enjoyment. Those who have exhausted every kind of enjoyment, and who have had no pleasures ungratified, are led to suicide from a weariness of life: who can live, when all power of feeling is gone?

The following is the most extraordinary and remarkable instance known of the manner in which habit, and a frequent repetition of the same impressions, wear out by degrees the sensibility of organs:—A shepherd, about the age of fifteen, became addicted to onanism, and to such a degree as to practise it seven or eight times in a day. Emission became at last so difficult, that he would strive for an hour, and then discharge only a few drops of blood. At the age of six-and-twenty, his hand became insufficient; all he could do, was to keep the penis in a continual state of priapism. He then bethought himself of tickling the internal part of his urethra, by means of a bit of wood six inches long; and he would spend in that occupation several hours, while tending his flock in the solitude of the mountains. By a continuation of this titillation for sixteen years, the canal of the urethra became hard, callous, and insensible. The piece of wood then became as ineffectual as his hand. At last, after much fruitless effort, G—— one day in despair drew from his pocket a blunt knife, and made an incision into his glans along the course of the urethra: this operation, which would have been painful to any one else, was in him attended with a sensation of pleasure, followed by a copious emission. He had recourse to his new discovery every time his desires returned. When, after an incision into the cavernous bodies, the blood flowed profusely, he stopped the hæmorrhage by applying around the penis a pretty tight ligature. At last, after repeating the same process perhaps a thousand times, he ended in splitting his penis into two equal parts, from the meatus urinarius to the scrotum, very near to the symphysis pubis. When he had got so far, unable to carry his incision any farther, and again reduced to new privations, he had recourse to a piece of wood shorter than the former: he introduced it into what remained of the urethra, and exciting at pleasure the extremities of the ejaculatory ducts, he provoked easily the discharge of semen. He continued this about ten years: after that long space of time, he one day introduced his bit of wood so carelessly, that it slipped from his fingers and dropped into the bladder. Excruciating pain and serious symptoms came on. The patient was conveyed to the hospital at Narbonne. The surgeon, surprised at the sight of two penes of ordinary size, both capable of erection, and in that stage diverging on both sides, and seeing besides, from the scars and from the callous edges of the division, that this conformation was not congenial, obliged the patient to give him an account of his life, which he did, with the details which have been related. This wretch was cut as for the stone, recovered of the operation; but died three months after, of an abscess in the right side of the chest, his phthisical state having been evidently brought on by the practice of onanism carried on nearly forty years.*

The habit of suffering renders us, in the end, insensible to pain: but every thing in this world is balanced; and if habit lightens our evils by

* Chopart, Maladies des Voies Urinaires, tome ii.

blunting sensibility, it, on the other hand, drains the source of our sweetest enjoyments. Pleasure and pain—these two extremes of sensation, in a manner approximate to each other, and become indifferent to him who is accustomed to them. Hence arises inconstancy, or rather, that insatiable desire of varying the objects of our inclinations, that imperious want of new emotions; hence we possess with indifference what we pursued with the utmost ardour and perseverance, and even cease to be impressed by those charms which once held us captivated.

A striking instance of the powerful influence of habit on the action of organs is afforded by that criminal who, we are told by Sanctorius, was taken ill on being removed from a noisome dungeon, and did not recover till he was replaced in the impure air to which he had been long accustomed. Mithridates, that formidable rival of the Roman power, dreading to be taken alive by his enemies, tried in vain to put an end to his life by taking large doses of the most subtle poisons, because he had long inured himself to their action.* It has, therefore, been justly said of habit, that it is a second nature, whose laws ought to be respected.

The organs of generation in women, in consequence of their lively sensibility, are in an especial manner submitted to the powerful influence of habit. The womb, after a miscarriage, has a tendency to a renewal of the same occurrence when the same period of pregnancy recurs; so that the greatest precautions are necessary to prevent abortion in women who are subject to it, when they have reached the month in which they before miscarried.

May not death be considered as a natural consequence of the laws of sensibility? Life, depending on the continual excitement of the living solids by the fluids which moisten them, ceases, because the parts endowed with sensibility and contractility, after long habitude of the impressions of those fluids, lose their capacity of feeling them. Their action, gradually extinguished, would perhaps revive, if the energy of the stimulating power were increased.

A knowledge of the power of habit is a useful guide in the application of remedies, the greater part of which operate in the cure of diseases, only by modifying sensibility. A wound in which lint has kept up the degree of inflammation necessary to cicatrisation, becomes insensible to that application, the parts become spongy and soft, and the cure is protracted. The lint should then be covered with an irritating powder, and the pledgets soaked in an active fluid: one may safely increase the doses of a medicine which has been long employed. Thus, in the treatment of the venereal disease by mercurials, the dose is to be gradually increased: with the same view, Frederick Hoffman recommended, in the treatment of chronic diseases, that the remedies should be suspended for a time and then resumed, lest the system should get accustomed to them, and their influence be lost. The same motive should lead one to vary the treatment, and to employ, in succession, those medicines to which nearly the same qualities are assigned, for each of them call forth the sensibility in a peculiar manner. The nervous system may be compared to an earth abounding in various juices, and for a full display of whose fecundity it is necessary that the husbandman commit to it the germs of various plants.

It is very remarkable, that habit, or the frequent repetition of the same act, which uniformly, under all circumstances and in all organs, blunts

* In some very rare cases, habit produces a quite contrary effect. Cullen states, that he knew persons so accustomed to excite vomiting in themselves, that the twentieth part of a grain of tartar emetic was sufficient to excite a convulsive action of the stomach.

physical sensibility, should improve the intellect,* and increase the facility and activity of execution of all the operations of the understanding, or of the actions which depend on them. "*Habit impairs the sensitive power, and improves the judgment.*" Bichât was therefore incorrect, when, in his distinction of the organs which are subservient to the functions of assimilation, from those which serve to keep up our relation with the surrounding objects, he maintained, that the sensibility of the latter becomes more exquisite, while the sensibility of the former becomes impaired from habit.

But can a painter, because he judges more correctly than the ignorant of the beauties of a picture, be said to see it better? Surely not; for he may, with a sight far less penetrating and more infirm, form a more accurate analysis, from the habit which he has acquired, and judge with a great deal more promptitude and certainty, of the several parts and of the whole; just as the practised ear of the musician seizes, in a piece of music, and during the most rapid execution, the expression and the value of all the notes and tones. The error has arisen, from its being forgotten, that, correctly speaking, it is not the eyes that see, or the ears that hear; that the impressions produced by the sounds on these organs are but the occasional cause of the sensation, or of the perception of which the brain is the exclusive seat. Which has the more delicate sense of hearing, the North American savage, who hears the noise of the step of his enemies at distances that astonishes us; or the artist who does not hear a person speaking at the distance of fifty paces from him, but who directs with judgment all the operations of a great orchestra, and who distinguishes skilfully the effect of each part?

Bring down to a frugal Pythagorean regimen one of our modern epicures: his palate, exhausted of its sensibility by the most savoury dishes, by ardent liquors, and the most exquisite ragoûts, will discover no taste in dry bread. Let him, however, live on bread, if he can, for some time; it will soon appear to him to have a grateful taste, as it does to those who make it their principal article of food, or who take it only with substances which have not a very distinct taste. Although, with the sense of smell, that of taste furnishes us only with ideas the most directly connected with our preservation, those which most turn upon the wants of our animal nature; although we retain with difficulty the impressions of these senses, and that, to enable us to retain them, they must be often repeated;—the epicure had so carefully analysed them, that he had attained to the discernment of the faintest differences of taste, all those delicacies of sensation, which, as Montesquieu said, are lost to us vulgar eaters.

The motions, under the direction of the will, acquire, by the precision of the determinations, the same aptness, facility, and readiness; and the dancer, who surprises us with his agility, has reflected, more than might be imagined, on the very complicated steps of which a ballet is composed.

Morbid sensibility is equally under the influence of habit. I have always observed, that discharges from the urethra become less painful from their frequency. There is nothing, down to disease itself, that is not made lighter by habit, as has been well observed by the old man of Cos.

It remains then demonstrated, even as a general thesis, that habit, or the frequent repetition of the same acts, whilst it regularly reduces physical sensibility, improves intelligence, and gives facility and promptness to all the motions that are under the direction of the will.

* As soon as an act fails to excite our sensations, in an inordinate degree at least, the reasoning powers proceed to analyse its nature: as sensation ceases, reflection commences; an exquisite state of the former is seldom compatible with a sound judgment.—*J. C.*

SECT. IX.—OF THE THE VITAL PRINCIPLE.*

The words *vital principle*, *vital force*, &c. do not express a being existing by itself, and independently of the actions by which it is manifested: it must be used only as an abridged formula, which serves to mark the total of the powers that animate living bodies, and distinguishes them from inert matter. So that whenever, in the course of this section, I shall use these terms, or any equivalent, it is to be taken as if I had said, the aggregate of the properties and laws that regulate the animal economy. This explanation is become indispensable, now that several writers, realising a mere abstraction, have spoken of the vital principle as of something very distinct from the body, as of a being altogether separable, which they have invested with feeling, and thought, and even deliberate intentions.

From the furthest antiquity, the many and striking differences of living and inorganic bodies, have led some philosophers to conceive in the former a principle of particular actions, a force which maintains the harmony of their functions, and directs them all to a common end, the preservation of individuals and of the species. This simple and luminous doctrine has remained, even to our own days, only modified in its passage through many years: and no one now disputes the existence of a principle of life, which subjects the beings that enjoy it to a system of laws different from those which inanimate beings obey; a force which might be characterised as withdrawing the bodies it animates from the absolute dominion of chemical affinities, which would else, from the multiplicity of their elements, act on them with great power; and as maintaining them in a nearly equal temperature, whatever may be that of the atmosphere. Its essence is not in preserving the aggregation of constituent molecules, but in drawing to it other molecules, which, by assimilation to the organs it prevades, replace those that are carried off in daily waste, and serve for their nourishment and growth.

All the phenomena that are to be observed in the living human body might be brought as proofs of the principle which animates it. The actions of the digestive organs on its food; the absorption, by the chylous vessels, of its nutritious parts; the circulation of these nutritious juices through the sanguineous system; the changes they undergo in their passage though the lungs and the secretory glands; the impressibility by outward objects; the power of approaching or avoiding them; in a word, all the functions that are carried on throughout the animal economy, proclaim its existence. But it is customary to take a proof of it yet more direct from the properties with which the organs of these functions are endowed. We have examined these properties, and we have seen that each of them presents us with at least two great modifications; that the last discovers three, which are, voluntary contractility, contractility involuntary and insensible, Stahl's tonic motion; and lastly, contractility involuntary and sensible, as that of the heart and the intestines.

If it is useful to analyse in order to know, it is of equal importance not to multiply causes, from misconceiving the nature of effects. And if, on the one hand, the multitude of the phenomena of life inclines us to the belief of many causes to produce them; the unfailing harmony that pervades all the actions, their mutual connexions and reciprocal dependencies, point

* See APPENDIX, Note A.

much more decisively to a sole agent, as causing, directing, and controlling these phenomena.

The hypothesis of the vital principle is to the philosophy of living beings what attraction is to astronomy. To calculate the revolutions of the planets, this science is compelled to recognise a force, which draws them constantly towards the sun, and constrains their tendency to fly from it, within the measured distance of those ellipses which they describe around that common centre of light and heat, which dispenses to them, as they roll, the precious germs of life and of fertility. We are about to speak of this force, to which all the powers that animate each separate organ join themselves, and in which all the vital powers are blended; but under the declaration, for the second time, of using the term only in a metaphorical sense. Without this precaution, I might lead you into all the false reasonings which those have fallen into who have assigned to it a real and separate existence.

The vital power is in perpetual strife with the powers that govern inanimate bodies. The laws of individual nature are, according to the saying of antiquity, for ever struggling against those of universal nature: and life, which is only this contest prolonged, in favour altogether of the vital powers during health, but with uncertain issue in disease, is at an end the moment in which the bodies endowed with it fall again into the system of lifeless being. This constant opposition of vital to physical laws, both mechanical and chemical, does not withdraw altogether living bodies from the control of these laws. There are effects always going on in the living being, chemical, physical, and mechanical: only these effects are constantly influenced, modified, and altered by the powers of life.*

Why, when we stand up, are not all the humours carried down to the lower parts, by the force of gravitation? The vital power resists the completion of this hydrostatic phenomenon, and neutralises this tendency of the fluids, the more successfully as the individual is more robust and vigorous. If it is one enfeebled by previous disease, the propensity will be but imperfectly repressed: the feet, after a certain time, swell; and this œdematous swelling can be ascribed only to the insufficient energy of the vital powers, which determine the distribution of the fluids, &c.

When a tumbler throws himself backwards, the blood does not flow altogether to his head, though this is become the lowest part: yet the natural tendency of fluids downwards is not altogether overcome, it is only diminished; for if he preserve long the same attitude, the struggle of the hydraulic and vital powers becomes unequal; the former prevail; they accumulate the blood upon the brain, and the man dies.

The following experiment proves incontestably what has just been said of the power of resistance, which, in the human body, more or less, effectually counterbalances the force of physical laws. I applied bags filled with very hot sand along the leg and foot of a man whose artery had been tied by two ligatures, in the hollow of the ham, for popliteal aneurism. Not only the limb was not chilled, which is what happens when the course of the blood is intercepted, but the extremity thus covered acquired a heat much above the ordinary temperature of the body. The same apparatus applied to the sound leg did not produce this excess of heat certainly, because the fulness of life in that limb resisted the physical action.

* In proof of this may be adduced the observation long since made by Dr. Alexander, that the range of temperature most favourable to the putrefaction of dead animal matter, being between 86° and 100° of Fahrenheit, includes the usual standard of human heat.—*J. C.*

The vital principle seems to act with the greater energy as the sphere of its activity is narrowed; which has led Pliny to say, that it was chiefly in the smallest things that Nature has shewn the fulness of her power.*

The circulation is quicker, the pulse more frequent, the determinations more prompt, in men of short stature. Such was the great Alexander: never did man of colossal make display great activity of imagination: none of them have glowed with the fire of genius. Slow in their actions, moderate in their desires, they obey without murmuring the will that governs them, and seem made for slavery. Agrippa (says Omilius Probus, in his History of Augustus) advised that they should disband the Spanish guard, and that, in its room, Cæsar should choose one of German, "wotting well, that in these large bodies there was little of coverte malice, and yet lesse of subtiltie, and that it was a people more minded to be ruled than to rule."

To judge soundly of the remarkable difference which inequality of stature brings into the character, compare extremes; set against a Colossus a little man of diminutive stature; granting, nevertheless, to this last full and vigorous health. You may guess that he is talkative, stirring, always in action, always changing his place; one would say that he is labouring to recover in time what he has lost in space. The probable reason of this difference in the vital activity, following the difference of stature, arises from the relative bulk of the primary organs of life. The heart, the viscera of digestion, &c. are of nearly the same bulk in all men: in all, the great cavities are nearly of the same extent, and it is principally in the length of the lower limbs that the difference of stature will be found to lie. It is easily conceivable, that the viscera supplying the same quantity of nutritious juices to a smaller bulk, that the heart giving the same impulse to blood which is to traverse a shorter course, all the functions will be executed with greater rapidity and energy.

By an obvious consequence, the diseases of little men have a more acute character; they are more vehement, and tend more rapidly to their crisis.† They have in them something of the velocity, I would even say the instability, of morbid reaction during infancy. There is nothing, even to the duration of life, on which the differences of stature have not some influence. With this suspicion, and some curiosity to ascertain its justness, I have made inquiries in the hospitals where people in advanced life are taken in, and I found them, for the most part, occupied by old men above the middle size; so that reasoning and observation concur in shewing that, all things else being equal, those of superior stature have a grounded hope of prolonging their life beyond the ordinary term.

I have observed, with many others, that the whole body unfailingly receives an increase of vigour from the amputation of a limb. Frequently, after the loss of a part of the body, you will see a manifest change take place in the temperament; those that were weak, even before the disease which brings on the necessity of the operation, becoming robust; affections, chronic from debility, such as scrofula, tabes mesenterica, dissipated; and glandular swellings resolved;—phenomena which indicate a very remarkable increase in the actions of all the organs.‡

* *Nusquam magis quàm in minimis tota est Natura.* Hist. Nat. lib. ii. cap. 2.

† The acute diseases of tropical countries, especially fever, prove more fatal to short men, or those of middle size, than to the tall.—*J. C.*

‡ The extraordinary development of an organ never takes place but at the expense of those about it, of which it draws off the juices. Aristotle observes, that the lower extremities are most always dry and wasted in those who are of ardent temperament, or in habits of frequent venery. Hippocrates relates (in his work *De ære, locis, et aquis*, Foës: fol. 293),

The parts most remote from the centre of circulation are, in general, less alive than those which are nearer. Wounds of the legs and feet are more liable to ulcerate, because, besides the circulation of the fluids, which the slightest weakness greatly retards in them, their life is too feeble for their wounds to go quickly through their periods, and readily cicatrise. The toes freeze first, when we remain too long exposed to severe cold: it is in them, too, that the mortification begins, which sometimes attacks a limb after the ligature of its vessels.

Thus, although we may say that the principle of life is not seated in any part of our being, that it animates every system of organs, every separate organ, every living molecule, that it endows them with different properties, and assigns to them, in some sort, specific characters, it must be confessed that there are in the living body some parts more alive, from which all the others seem to derive motion and life. We have already seen, that these central organs, these foci of vitality, in whose life that of the whole body is involved, diminish gradually in number in the animal kinds as they are more removed from man; whilst the fewer they are, the more they are spread out over the body; so that life is more generally diffused, and its phenomena less rigorously and strictly connected, as we descend in the scale of being, from the red and warm-blooded, to the red and cold-blooded animals, from these to the mollusca, the crustacea, worms and insects, to the polypus, who forms the extreme link of the animal chain; and, lastly, to plants, of which not a few, like the zoophytes, so similar to them in many respects, are endowed with the remarkable property of reproduction by slips, which implies, that each part contains the aggregate of organs necessary to life, and can exist alone.

The vital principle has by some been confounded with the rational soul; but others have distinguished it from that emanation of Divinity, to which, as much as to the perfection of his organisation, man owes his superiority to all the animal kinds. What bond unites the material principle, which receives impressions and transmits them to the intelligence, which feels, perceives, examines, compares, judges, and reasons on them? Were man one, says Hippocrates, did his material principle make up his whole nature, pleasure and pain would be as nothing to him, he would be without sensation; for how could he account to himself for impressions? *Si unus esset homo, non doleret, quia non sciret unde doleret.* Here we stand on the confines of physiology and metaphysics: let us beware of setting foot in the dim paths that are before us: the torch of observation would yield but ineffectual light, too faint to dispel the thick darkness that lies over them.

The vital power is merely the *vis medicatrix naturæ*, more powerful than the physician in the cure of many diseases; the art of the physician consisting, in most cases, in awakening or directing the action of that power. When a thorn is thrust into a part endowed with sensibility, a sharp pain is felt, the fluids rush in abundance to the part, it becomes red and swollen; all the vital powers are excited, the sensibility becomes more acute, the contractility greater, and the temperature rises. Does not this increase of vital energy in the injured part, this process which takes place around the substance that is the cause of the disorder, those means which are pro-

that the Scythian women seared their right breast, that the arm on that side might grow in size and strength. Galen speaks of athletes, who, in his time, kept the sexual organs in the most entire inaction,—that, withered, shrunk, and perished, in some sort, by this absolute repose, they might not draw off the nutritious juices from the sole nourishment of the muscular organs. A young man who has several times carried off the prize by running at the public fêtes, abstains from venery for some months before entering the lists, in perfect certainty of victory after this privation.

vided to expel it, indicate the existence of a preserving principle, incessantly watching over the harmony of the functions, and struggling against all the powers that may tend to interrupt its exercise, or to annihilate the vital motion ?

*Theory of inflammation.**—Inflammation may, I believe, be defined, *the increase of vital properties in the parts which it affects.* Sensibility becomes more acute in the part so affected, its contractility greater ; and from that increase of sensibility and action arise all the symptoms characteristic of inflammation. Thus the pain, the swelling, the redness, the heat, and the difference in the state of the secretions, denote in the part a more energetic and active vitality.

Those who have objected to the definition which I have given of inflammation, have evidently mistaken the functions of the organs for their properties. It is very true, that inflammation of the eye is attended with loss of sight : but that circumstance depends on the opacity of the transparent parts, which should transmit the luminous rays to the retina. The sight is prevented by a mechanical obstacle ; but the sensibility of the organ is augmented to such a degree, that the faintest light reaching the bottom of the eye through the transparent cornea dimmed by the congestion of the vessels, causes in it intolerable pain. On this principle, darkness is universally recommended to patients affected with ophthalmia. In like manner, when a muscle is inflamed, the action of the fibre, its decurtation, is prevented by the congestion in the cellular membrane, which covers it, and fills its interstices. The cause preventing contraction, or the exercise of contractility, is mechanical, and may be compared to that which, in an inflamed lung, opposes the admission of air and the passage of the blood from the right to the left side of the heart. Can any one call in question the increase of vital action in peripneumony ? I am, therefore, of opinion, that the above definition is better than that proposed by Bichât in his *Anatomie Générale*,—a work of later date than the first edition of these *Elements of Physiology*, and in which he makes inflammation to consist in the increase of those vital properties which he terms insensible.

All the parts of the human body, with the exception of the epidermis and its different productions, as the nails and the hair, appear capable of inflammation. One might include among these "epidermoid" parts, certain dry and slender tendons, as those of the flexors of the fingers, which when pricked, lacerated, and irritated in a thousand ways, are insensible to pain, and remain uninjured in the midst of a whitlow, though attended with suppuration of all the neighbouring soft parts ; and when exposed to the air, they exfoliate instead of granulating. Organisation is so indistinct in all these parts, life so feeble and languid, that they remain insensible to the impression of all those causes which might tend to increase its activity.

The degree of sensibility in a part, the number and size of the nerves and vessels which are sent into it, determine the degree of its aptitude to inflammation ; thus, the bones and cartilages inflame with considerable difficulty. When one of these parts is laid bare, the first effect of irritation to which it is exposed, is a softening of its substance. When a bone is laid bare it becomes cartilaginous and softens, in consequence of the absorption of the phosphate of lime which fills up the interstices of its tissue ; and it is only after this kind of incarnation that fleshy granulations begin to spout, as may be observed on the extremities of bones after amputation. The difficulty with which inflammation is set up in the harder parts of the body explains why, before the twelfth or fifteenth day after a

* See APPENDIX, Note G.

fracture, it is of little consequence towards union of the bone that the fractured ends should be placed in apposition; not that it is right to wait so long before applying the proper bandages, which are indispensable from the first, to prevent the pain and laceration occasioned by the displaced bone.

The blood is determined, from all quarters, towards the irritated and painful part, which swells and assumes a red colour from the presence of that fluid. The swelling would be unlimited, if, at the same time that the arteries increase in power and calibre to occasion that determination, the veins and lymphatics did not acquire a corresponding energy, to enable them to relieve the part of the fluids which have accumulated in it, and which irritation is constantly determining to it. The power of irritability and contractility increases with sensibility; the circulation is more rapid in the inflamed part; the pulsations of the capillary vessels are manifest. The part is likewise hotter; because in a given time there passes through its tissue more arterial blood, from which a larger quantity of caloric is disengaged, and the continued effects of the pulmonary respiration are better marked in it than in any other organ.

It forms no part of our intention to treat of the varieties of inflammation: they depend principally on the structure of the organ which is affected, on the violence and rapidity of the symptoms, and on its effects.*

Is not the turgescence of an inflamed part occasioned in the same manner as in parts subject to erection, as the corpora cavernosa of the penis and of the clitoris, the nipples, the iris, &c.? In erection of the penis, as in inflammation, there is an irritation, a determination of fluids to the part, an increase of sensibility and contractility; yet its condition is not that of inflammation. Nature has so disposed the organisation of these parts, that they can sustain, without injury, those instantaneous augmentations of vital energy necessary to the exercise of the functions performed by the organs to which they belong. As in inflammation, these congestions disappear when the cause of irritation has ceased to act; thus, the pupil dilates because the iris recedes when the eye is no longer exposed to the rays of a vivid light. The penis returns to its naturally flaccid and soft state when no irritation operates to determine to it the fluids, whose presence, as long as the erection lasts, is easily explained by the continuance of the irritation, without its being necessary to have recourse to mechanical explanations to account for that phenomenon. When the irritation which produces the vital turgescence of the penis, or iris, is carried too far, or continues too long, the natural congestion becomes morbid. It is well known that priapism is frequently attended with mortification of the penis; and that the too long continued action of light on the eye brings on inflammation of that organ.

The preceding observations on inflammation shew that an acquaintance with its phenomena is useful, even in a physiological view. The vital processes, which in some organs take place in so obscure a manner that they are imperceptible, acquire in inflammation a character of rapidity and intensity, which renders it much easier to observe and recognise them. Considered in a general and abstract point of view, and merely with a reference to its object, inflammation may be considered as a means employed by nature to repel the influence of noxious agents, which, when introduced within the body, or on its surface, she has no power of resisting but by a more active development of the powers which animate it.

* They depend also upon the causes which produced them, on the habit and constitution of the patient, and the endemic or epidemic influences operating on his frame either previous to or during the progress of the inflammatory disease.—*J. C.*

During the severe winter of 1793, the chemist Pelletier repeated the celebrated experiment of freezing mercury, and obtained a solid ball in the bulb of a barometer, which he had for a long while kept immersed in the midst of a quantity of ice, continually moistened with nitric acid. When the metal had attained a completely solid state, he drew the ball from the bulb, and placed it on his hand. The heat of the part, joined to that of the atmosphere, soon restored the quicksilver to its fluid state: at the same instant he experienced in his hand so intolerable a degree of cold, that he was obliged to drop the quicksilver instantly. There soon came on, in the painful and chilled part, a phlegmonous inflammation, which was cured by resolution. Quicksilver, in a solid state, is one of the coldest bodies in nature: how very rapidly the caloric must have been carried off in this case, and how deep the impression must have been in the palm of the hand, doubly affected by the cold and by the vital re-action, which terminated in inflammation! I have produced a similar effect, by endeavouring to melt a piece of ice in my hand, during the heat of summer. In this experiment, the impression of cold is soon succeeded by a sensation of acute pain, and extraordinary throbbings in the hand and fore-arm. When the two hands are afterwards compared, that which held the piece of ice is extremely red, from the congestion of blood in the cutaneous capillary tissue, and is very different in its appearance from that which was not the subject of experiment.

Analogous facts, if seriously considered, should induce the followers of Brown to apply to the effects of cold the distinction which he applied to debility, of direct and indirect. They would have no difficulty in ascertaining, that, in its medical application, that negative state of caloric which is directly debilitating, may, nevertheless, by the re-action which it excites, be considered as an indirect tonic.

SECT. X.—OF THE SYSTEM OF THE GREAT SYMPATHETIC NERVES.*

The great sympathetic nerves are to be considered as the bond destined to unite the organs of the nutritive functions, by whose action man grows, is evolved, and incessantly repairs the continual waste attending the vital motions. They form a nervous system, very distinct from the system of the cerebral nerves; and, as the latter are the instruments of the functions by which we hold intercourse with external objects, the great sympathetic nerves supply motion and life to the organs of the inward, assimilating, or nutritive functions.

In animals without vertebræ, may not the nervous system, which floats in the great cavities, with the viscera which they contain, be considered as consisting entirely of the great sympathetics?† These nerves are princi-

* See APPENDIX, Note H.

† TREVIRANUS, in his *Biologie*, considers the knotted chord found in the abdomen of insects and worms to be the vertebral ganglia of the sympathetic nerve. That it cannot be considered a spinal chord is evident. Its situation shews sufficiently the difference. The molluscæ, and many animals removed a little above this class in the scale of creation, possess merely single ganglia, from which proceed fibrilæ to the different organs. The great sympathetic nerve is the most general and the most original of all the nerves. Its characters are, however, modified in different classes. In worms and insects there are merely vertebral ganglia, without the cœliac ganglia of mammalia and birds; in the acephalous molluscæ there are the latter, without the former; in the cuttle-fish and snails there are single ganglia of both kinds. All these animals have no spinal marrow; fishes and reptiles have one, and also vertebral ganglia; but the cœliac is not fully developed in them as in birds and mammalia.

These remarks convey the sum of the observations made by those who have inquired into the subject: how, therefore, can the ganglial class of nerves be considered to arise from the cerebral and vertebral masses?—*J. C.*

pally distributed to the organs of inward life, whose activity in those animals seems to grow in proportion as their external senses, and their faculty of locomotion, are imperfect. If the great sympathetics exist in all the animals which have a distinct nervous system, do they not, in an especial manner, contain the principle of vegetable life, essential to the existence of every organised body possessing the power of digestion, absorption, circulation, secretion, and nutrition? Finally, is it not probable, that in man the system of the sympathetic nerves has a very great share in occasioning a number of diseases; and that the impressions with which patients are affected, are to be referred to their numerous ganglions, while the brain is exclusively the seat of intellect and thought?*

These suggestions will, doubtless, be answered in the affirmative, if one considers the origin, the distribution, and the peculiar structure of these nerves, the acute sensibility of their branches, as well as the disorders attending their injury.

Extended along the vertebral column, from the base of the skull to the lower part of the sacrum, these great nerves, in some measure parasitic, do not arise from the branches supplied them by the fifth and sixth pairs arising from each side of the brain: they live, and are nourished, as it were, at the expense of all the nerves of the spinal marrow, from which they receive branches, so that there is not one of them from which one can say that the great sympathetics arise exclusively. The numerous ganglions which are distributed along their course, divide them into so many small systems, from which arise the nerves of the organs nearest to them. Amid these bulgings, considered by several physiologists as so many little brains, in which is performed the elaboration of the fluid which they transmit to the nerves, no one is of more importance than the semi-lunar ganglion, situated behind the organs which occupy the epigastric region; and from which those nerves originate which are distributed to the greater part of the viscera of the abdomen. It is to the region occupied by that ganglion, in which the great sympathetic nerves unite, and which may be considered as the centre of the system formed by their union, that we refer all our agreeable sensations; there it is that we feel, in sadness, a constriction which is commonly referred to the heart. Thence, in the sad emotions of the soul, seem to originate those painful irradiations which trouble and disorder the exercise of all the functions.†

The numerous filaments of the great sympathetic nerves are finer, they are not of the same whitish colour, nor of the same consistence as the filaments of the cerebral nerves. On that account, they are less easily dissected,‡ the nervous fibrilæ are less distinct, their reddish chords are moister, and they appear formed of a more homogeneous substance: their membraneous coverings are less considerable. They are likewise endowed with a more acute and more delicate sensibility. Every one knows the danger attending wounds of the mesentery, a membraneous duplicature,

* These opinions on the uses of the great sympathetic nerves, are explained in my essay on the connexion of life with the circulation. This essay was published before any thing that has appeared on the same subject. Consult the "Mémoires de la Societé Médicale pour l'an VII."

† Consult, on the subject of the epigastric centre, Van Helmont, who calls it the *Archæus*; Buffon, Bordeu, Barthez, and Lacaze, who give it the name of the *phrenic centre*, because they ascribe to the diaphragm what belongs to the nervous ganglions placed in front of its crura.

‡ One of the best modes of dissecting them, is to macerate the part in which we wish to trace their ramifications, during two or three days in water; then place it for a short time in a very dilute acid, or warm spirits, or in oil of turpentine. The filaments of these nerves may be then traced more distinctly. Other processes, which are complex, are requisite to the dissection of the minuter ramifications, especially those which supply the blood-vessels.—*J. C.*

in itself insensible; but containing such numerous nerves destined to the intestinal tube, that the most pointed instrument can scarcely wound the mesentery without injuring some of their branches. The pain attending affections of the great sympathetic nerves is of a very peculiar kind; it leads directly to the extinction of the vital power. It is a well-known fact, that a bruise of the testicles overpowers, in a moment, the strongest man. Every one knows, that patients who die of a strangulated hernia, of volvulus, or of any other affection of the same kind, die in the most distressing anguish; their heart feels oppressed, and they are tormented with constant vomiting. Intestinal and nephritic colics are attended with the same sort of pain: that attending injection of the tunica vaginalis, in hydrocele, is of the same kind. And one expects a favourable event of the operation only in those cases in which the patient has felt pain along the spermatic chord, in the course of the spermatic nerves, which arise, as it is well known, from the renal plexus. In three cases of wounds of the abdomen, I was led by the nature of the pain which the patients suffered to prognosticate that the wounds had penetrated: the event justified my prognostic. In all these affections of the great sympathetic nerves, the pulse is frequent and hard, the face is covered with a cold sweat, the features are sunk; all the symptoms are alarming, and soon terminate fatally.

The use of the system of the great sympathetic nerves is, not merely to establish a closer connexion and a greater union between all the organs which perform the functions of assimilation, but likewise to free those parts from the influence of the will,—a power of the mind so fickle and so varying, that life would be in constant danger, if we had it in our power to stop or suspend the exercise of the functions with which it is essentially connected.

If we consider what are the organs to which the functions of assimilation are intrusted, and which receive their nervous influence from the great sympathetic nerves, we shall find that the action of the greater number is wholly independent of the control of the will.* The heart, the stomach, the intestinal canal, &c. do not obey the will, and seem to possess a more insulated and more independent existence, and to act and rest without any influence on our part. Some of these organs, as the bladder, the rectum, and the muscles of respiration, which do not receive their nerves exclusively from the great sympathetics, are obedient to the will, and receive from the brain the principle of motion; the former from the branches which the sacral nerves send to the hypogastric plexuses; the diaphragm from the nerves which it receives from the fifth and sixth cervical pairs.

The great sympathetic nerves supply the diaphragm, the rectum, and bladder, only with nerves of sensation. This provision was a very necessary one, for if, as is the case with the heart and the intestines, these parts had received their nerves of motion from the great sympathetics, their action would have been independent of the will, as is the case with all the parts which these nerves supply with motion. The bladder and rectum, placed at the extremities of the digestive apparatus, and destined to serve as reservoirs to the excrementitious residue of our solid and liquid aliments,

* All those parts which receive their nerves from ganglions are equally independent. Professor Chaussier thinks, that the upper filaments of the great sympathetic nerves ascend along the internal carotid, and join the spheno-palatine and lenticular ganglions. M. Ribes thinks he has ascertained by dissection that several very long and slender filaments follow the course of the branches of the internal carotid, and like them are sent to the base of the brain, beyond which they cannot be traced. I have myself observed in dissection these filaments around the branches of the internal carotid artery, but I had always considered them to be formed of cellular substance.

would have been constantly evacuating their contents as fast as the substances which are destined to be retained within them for some time reached their cavity.

On the other hand, if the diaphragm had received its nerves of motion from the great sympathetics, respiration would have ceased to be a voluntary function, of which we might at pleasure accelerate, slacken, or even completely suspend the action. To prove that the act of respiration is under the control of the will, we may have recourse to analogy, and adduce the instance of reptiles, as lizards, frogs, serpents, salamanders, and toads, which are cold-blooded animals, and in which this function is manifestly voluntary. We may further mention those slaves, who, we are told by Galen, put themselves to death when summoned before their executioners or judges. According to that physiologist, and others, they choaked themselves, by swallowing their tongue. But it is sufficient to know how the muscles that bind down the tongue are situated, and the degree of motion which they allow, to see how little ground there is for that opinion. The action of the brain would, in that case, have been no longer necessary to the maintenance of life; in an animal without a brain, respiration would have continued, and the circulation would not have been interrupted. The death of that viscus would not have been attended with the sudden death of all the rest.

The nerves which arise from the spinal marrow, and which give to the diaphragm the power of contraction—a power which that muscle loses suddenly if these nerves be tied—appear to me the chief links which unite the internal assimilating, or nutritive functions, to those which keep up the relation of the animal with external objects. Without this bond of union, the series of vital phenomena would have been less close, and their dependence less necessary. Had it not been for the necessity that the diaphragm should receive from the brain, by means of the phrenic nerves, the principle which determines its contractions, acephalous animals, which are born without that organ, might continue to live as they did before birth, when the organs of nutritive life received blood which had undergone, in the lungs of the mother, the changes necessary to life. But where the bond which united them to the mother is destroyed, obliged themselves to produce in their fluids the necessary changes, by the inhalation of the vivifying principle contained in the atmosphere, they no longer can obey that necessity: the organs of respiration are deficient in the principle which should excite them.

When an internal inflammation is of small extent,* and is seated in a part in which there are not many nerves, and whose tissue yields easily to the humours which irritation determines into it, the whole morbid action takes place in the affected part, and the general order of the functions is not sensibly deranged. But when inflammation takes place in a part endowed with much sensibility, or of a close texture, as the fingers and toes, then fever comes on, because a sympathy in the morbid action takes place between the diseased part and the rest of the system. This diffusion of the

* A thousand pustules in the small-pox occasion only a moderate degree of fever, if they are at a distance from each other; but if the disease is confluent, that is, if the pustules are close together, and run into each other, the fever becomes considerable, and the patient's life is endangered. The fleshy granulations which sprout in abundance from an ulcerated surface, are so many small phlegmons unaccompanied by a febrile state; but if brought close to each other by irritation, that condition will not fail to ensue. Vaccination is not, in the greater number of cases, attended by the slightest febrile action, if, as I always have done, the punctures are made at a certain distance from each other, so that the inflammatory areolæ may not run into each other.

local action almost infallibly takes place when inflammation occurs in one of the organs of the assimilating functions. This effect may be considered as uniform, though Morgagni mentions several instances of inflammation of the liver, marked by no peculiar symptoms.

A knowledge of the great sympathetic nerves accounts for this difference. When an external part is affected with inflammation, the irritation which it suffers is, by means of its nerves, propagated to the brain, which by a re-action,* called by Vicq-d'Azyr (who on this subject has only developed the opinions of Van Helmont) internal nervous action, transmits that irritation to the heart, to the organs of respiration, of digestion, and of secretion. in which the phenomena, denoting a febrile state, are principally evolved, When, on the contrary, the heart, the lungs, or any other internal organ, is affected with acute inflammation, all the viscera partake in the derangement with which any one of them is affected, and without the intervention of the brain. They are all intimately connected by the filaments which they receive from the great sympathetic nerves; and by means of that nervous system, which is in an especial manner appropriated to them, they carry on a more intimate intercourse of sensations and affections. Besides, the derangement of the important functions intrusted to the diseased organs, is necessarily attended with proportionate changes in all the acts of the animal economy, in the same manner, no doubt, as the defect of one wheel interrupts or disturbs the mechanism of the whole machine.

There exists in the stomach a union of the cerebral and sympathetic nerves, which explains the manifest dependency of this viscus on the brain; a dependency so marked, that every strong affection of the soul, every violent agitation of the mind, weakens, or even totally suspends, the action of digestion in the stomach. "This combination of cerebral and sympathetic nerves likewise accounts for various phenomena connected with disease, and for the operation of several remedies in removing it."†

Sect. XI.—OF THE RELATIONS OF PHYSIOLOGY TO SEVERAL OTHER SCIENCES.

It would be entertaining a very incorrect notion of the science of living man, to imagine, with some authors, that it solely consists in the application of the laws of natural philosophy to the explanation of the phenomena of the animal economy. Physiology is an independent science, resting upon truths of its own, which it draws from the observation of those actions which, in their aggregate succession and connexion, constitute life. It is enriched, it is true, with facts furnished to it by natural philosophy, chemistry, and mathematics; but what it has borrowed from these is accessory merely, and does not form an essential part of the edifice of the science. Thus, the better to understand the mechanism of hearing and vision, physiology borrows, from acoustics and optics, elementary notions on sound and light; and in order to obtain a more correct knowledge of the nature of our solids and fluids, and of the manner in which animal

* The cerebral re-action appears to be in no measure necessary to the induction of symptomatic fever: it may, however, contribute to its continuance. The irritation appears to be propagated to the heart in consequence of the numerous connexions which this organ holds, by means of the ganglial nerves, with the other viscera, and owing to the continuous reticulation of these nerves upon the arterial system from the heart to the capillary terminations of the vessels. See the APPENDIX, Note H, for further observations on this subject.—*J. C.*

† See the observations on the functions of the Stomach, and on the influence of the eight pair of nerves in Digestion, in the APPENDIX, Notes K and L.

substances are constantly passing from the one to the other of these two conditions, physiology calls in the aid of chemistry. Thus, geometry and mechanism furnish it with the means of better understanding the advantageous form of the organs, and the perfection of their structure.* Where the natural philosopher stops, the physician commences. *Ubi desinit physicus, ibi incipit medicus*, was well said by Aristotle.

No study carries along with it a more lively interest than that of the admirable relations existing between the conformation of our parts and the external objects to which they are applied. These relations are calculated with such precision, and laid down with such accuracy, that the organs of sense and of motion, considered in this point of view, may be regarded as the model of the most ingenious productions of art. So true it is, in the words of the great physician of Pergamus, that nature did every thing before art, and better.†

At the beginning of the last century, geometrical physicians, deceived by an appearance of rigid precision, attempted to explain every thing by the calibre of vessels, their length, their curvatures, the compound ratio of the action of solids, and the impulse of fluids. Hence were formed theories so very imperfect, that, as we shall see, in treating of several points of physiology, and especially of the force with which the heart acts, not one of those who proposed them coincides with those who have since followed their track. However, it does not admit of a doubt, that there occur, in the animal machine, effects which are referable to the laws of hydraulics. The brain, for example, required a large and constant supply of arterial blood, vivified by recent circulation through the lungs; but the too rapid and abrupt access of that fluid in the brain might have disordered its structure. Nature, therefore, has, as we shall mention in the article of the cerebral circulation, employed all the hydraulic resources in her power, to break the force with which the blood enters the brain, and to slacken its course.

Has man ever applied the laws of hydraulics in a more felicitous manner than nature, in the rete mirabile formed at the base of the brain by the carotids of quadrupeds?—an arrangement truly remarkable, without which the blood conveyed to the brain by those arteries, impelled by a force superior to that of the human heart, and not having to overcome the resistance of its own gravity, would infallibly have occasioned a disorganisation of that organ, whose consistence is so soft.

As to the application which is allowable of mathematical sciences, it may be said, that, as in physiology, but little is absolutely certain,‡ and much merely probable, we can reckon only on probabilities, and seek our elements in facts deduced from observation or experience; facts which, when collected and multiplied to a certain degree, lead to results of equal value with truths absolutely demonstrated.

* A knowledge of mathematics, and of the whole circle of natural philosophy, including more especially chemistry and natural history, and, in a more particular manner, human and comparative anatomy, is requisite to the successful study of physiology. This last branch of knowledge, although independent of some of these, is yet more easily acquired, and its difficulties are better explained, by a previous acquaintance with all of them. Pathology and the treatment of diseases, also, reflect a light upon physiology which they first derive from this productive source.—*J. C.*

† *Quandoquidem natura, ut arbitror, et prior tempore sit, et in operibus magis sapiens quàm ars.*—GALENUS *de Usu Partium*, lib. vii. cap. 13.

It was from observing the manner in which nature prevents the diffusion of light in the globe of the eye, that Euler was led to the improvement of his astronomical telescopes.

‡ This is to be understood as applying only to the causes of the phenomena, and not to the phenomena themselves; for physiology is perhaps richer than any other science, in facts unquestionable, and easily ascertained by observation.

The phenomena presented by living bodies vary incessantly in their activity, their intensity, and their velocity. How can mathematical formulæ apply to such variable elements? As well might you enclose in a frail vessel, hermetically sealed, a fluid subject to expansion, and of variable bulk. The motions of progression in man and in the animals afford, nevertheless, sufficiently correct applications of calculation. Calculation may likewise be applied with advantage to the measurement of the results of our different secretions, to ascertain the quantity of air or of aliment introduced into our organs, &c.

Among the principal causes which have retarded, in a considerable degree, the progress of physiology, may be enumerated the mistake of those who have endeavoured to explain all the phenomena of living bodies by a single science, as chemistry, hydraulics, &c., while the union of all these sciences will not account for the sum of these phenomena. The abuse, however, of these sciences should not be a reason for setting them aside altogether. The facts obtained from natural philosophy, chemistry, mechanics, and geometry, are so many means applicable to the solution of the great problem of the vital economy; a solution which, though as yet undiscovered, should not be considered as unattainable, and to which we shall approach the nearer as we attempt it with a greater number of data. But it cannot be too often repeated, that he alone can hope for that honour who, in the application of the laws of natural philosophy to living bodies, will take into account the powers inherent in organised nature, which control, with supreme influence, all the acts of life, and modify the results that appear most to depend on the laws by which inorganic bodies are governed.

Anatomy and physiology are united by such close relations, that it has been an opinion with some that they are absolutely inseparable. If physiology, say they, has for its object a knowledge of the functions carried on by our organs, how is one to understand their mechanism, without knowing the instruments by which they are performed? One might as well attempt to explain the manner in which the hand of a watch performs the circle of its diurnal revolution, without understanding the springs and numerous wheels which set it in motion. Haller is the first who established the connexion between anatomy and physiology, and who illustrated it in his great work. Since Haller, a great number of anatomists, and among them Sœmmering,* in a work recently published, have combined, as much as possible, these two sciences; the latter, in treating separately of each system of organs, explains what is best known of their uses and properties.

However close the connexion between anatomy and physiology, they have, nevertheless, appeared perfectly distinct to the greater number of authors, and we have several valuable works on anatomy, of which physiology occupies but a small part. This manner of embracing the two sciences appears to me attended with the greatest advantage: in fact, if the insulated description of organs suffices to the physiologist who wishes to study their functions, that method is attended with the disadvantage of furnishing few truly useful views in the practice of operative surgery. To render the knowledge of the human body more especially applicable to the practice of surgery, it is necessary not only to consider separately the different parts, but likewise to view them in their connexion, and to determine precisely their relations. The anatomist, who knows that the principal artery of the thigh is the crural; that, continued under the name

* J. Ch. Sœmmering, *de Corporis Humani Fabricâ*, 6 vols. 8vo. 1804.

of popliteal, it passes behind the knee in its way to the leg; that in its course it supplies with branches different parts of the limb; even though he knew perfectly the names, the number of these branches, the varieties to which they are subject, the parts to which they are distributed, would, nevertheless, possess a knowledge of that branch of the system, almost useless in the treatment of the diseases with which it may be affected. The situation of the artery, its direction, the parts which surround it, its precise relations to each of them, its superficial or deep-seated course, &c. are the only circumstances from which he can derive any advantage.

He who, in this point of view, cultivates anatomy, may be compared to the chemist: in the same manner as the latter is never better acquainted with a substance than when he is able to decompose it, and to reproduce it from a combination of its parts; so the anatomist is well acquainted with the body of man only when, having studied separately and with the greatest care each of his organs, and each of the systems formed by the collection of a certain number of similar organs, he is able to assign to each of them its place, to determine its relations, and the proportions which it bears in the structure of any one of our limbs. The study of the latter is much more difficult and extensive than that of the former; for, the chemist who decomposes and recompounds a well-known substance,—phosphate of lime, for instance,—attains only to the knowledge of its constituent principles and respective proportions: the phenomena of situation altogether escape him. The anatomist, on the other hand, who knows that such a part is composed of bones, of muscles, of nerves, of vessels, must know not only every one of these parts, and their relative bulk, but the exact place in which they are to be found.

Anatomy, pursued in this spirit, offers a field of wide extent: it is the art which Leibnitz called the analysis of situation, *analysis sitûs*; and the knowledge of it is too important not to require a separate place among the departments of medical knowledge. I will not pass over the motives that are alleged for combining anatomy and physiology in one course of instruction. Anatomy, confined to the mere description of the organs, is too dry and fatiguing; physiology throws over it interest and variety; it helps to ensure the attention of the hearers, who will retain more permanently what they have listened to with pleasure. Would not one think that physiological details were, for an audience, what is contrived for a sick and froward child, in the honey that is rubbed on the edge of the cup, to disguise the bitterness of the draught that is to recall him to health? In combining two objects, of which one has no interest but that of usefulness, whilst the other is engaging as well, the attention will be not merely divided, but altogether distracted; and the mind of those who read or listen will skim over dry details, to seize with avidity what furnishes more to its activity of intelligence. Anatomy is to physiology what geography is to history. General considerations on the situation, the size, the form, the relations, the structure of the organ, are an indispensable preparation to the perfect understanding of its functions: accordingly, you shall find much anatomy in physiological treatises, as you find much geographical detail in faithful historians.

I have said enough, I trust, to escape the reproach of not having filled my book with anatomical descriptions from the multitude of excellent works we possess on the anatomy of the human body. Let us now inquire what relation physiology bears to comparative anatomy.

If a machine can be perfectly known only after taking it to pieces, down to its simplest elements; if the whole mechanism of its performance can

be conceived only by examining separately the action of each different part composing it, comparative anatomy,—by aid of which we may study, in the great chain composing the various classes of the animal kingdom, the separate action of each organ, appreciate its absolute or relative importance, consider it at first insulated and reduced, so to speak, to its own powers, in order to determine what part it bears in the carrying on of a function,—comparative anatomy is of absolute necessity to him who would make great progress in the knowledge of man: it may be looked upon as a sort of *analytical method* of study, by means of which we more completely attain to the knowledge of ourselves.

In order to conceive rightly the operations of the human intellect, and explain the generation of the faculties of the soul, metaphysicians have imagined a statue, into which they have infused a gradual animation, by investing it, one by one, with our organs of sensation. Now nature has realised, in some sort, this dream of philosophy. There are animals to which she has entirely denied the organs of sight and hearing: in some, taste and smell seem to have no separate existence from touch; in others, she has exercised a sort of analysis on a system of parts which all concur in one function. It is thus, that in some animals, divesting the organ of hearing of the accessories allotted to collect, transmit, and modify the rays of sound, she has reduced it to a simple cavity, filled with a gelatinous fluid, in which float the extremities of the acoustic nerve, alone fitted to receive the impression of sound; a fact which overthrows all the hypotheses that had ascribed this sensation to other parts of the auditory apparatus.

Of all the physical sciences, comparative anatomy is that which furnishes the most useful facts to physiology.* Like physiology, it is concerned with organised living beings; there is, therefore, no need of watching against the false applications, so often made from the sciences, whose objects are matter inorganic and dead, or which study, in living beings, only the general properties of matter. Haller was so well aware of the utility of introducing this science into physiology, that he has brought together the greater part of the facts known in his time on the anatomy of animals, at the head of each chapter of his immortal work.

This general consideration of living and animated beings, so well adapted to unveiling the secret of our organisation, has this further advantage, that it enlarges the sphere of ideas of him who applies to it. Let him who aspires to that largeness of conception, so requisite in medicine, where facts are so multiplied and various, explanations so contradictory, and rules of conduct so unfixed, cast a general glance on this great division of organised beings, of which many, in their physical structure, so nearly resemble man, —he will see the sovereign Architect of the world distributing to all the elements of life and activity, giving to some a less power of motion, to others more; so that, formed all on one model, they seem only the infinitely varied but gradual shades of the same form, if forms have shades like colours; never passing abruptly from one to another, but rising or falling by gentle and due degrees, covering the interval that separates two different beings with many species that serve as a transition† from one to

* "The extensive examination of various structures," Mr. Lawrence very justly observes, "is not only a necessary ground-work for the edifice of general physiology, but it has thrown great light on the organisation and functions of the human frame. Whoever will reflect on our present knowledge of the digestive, respiratory, generative, or other processes of man, and will review the successive stages of its progress, will find that comparative anatomy has rendered us the most essential assistance."—*J. C.*

† The conception of a scale of being, which, as was said by C. Bonnet, connecting all the

the other, and which present a continuous series of advancement or degradation; organisation being constantly simplified in descending from man to the inferior creatures, but rising in complexity in re-ascending from those animals to man, who is the most complex being in nature, and was justly considered by ancient philosophy as the master-piece of the Creator.

If the intimate structure of our organs totally eludes our investigation, it is that the finest and most delicate of their constituent parts are of such minute dimensions that our senses have no hold on them. It is then well to have recourse to analogy, and to study the organisation of animals that exhibit the same organs on a larger scale. Thus the cellular texture of the lungs, which cannot be distinctly shewn in man, on account of the extreme minuteness of the smallest bronchiæ, may be satisfactorily seen in the vesicular lungs of salamanders and frogs. In like manner, the scales which cover the bodies of fishes and reptiles, or the legs of birds, give us a just idea of the structure of the epidermis, and of the arrangement of its small scales, which lie over each other, in a part of their surface.

The human structure being more complicated, must produce effects more numerous, and results more varied and more difficult to understand. In commencing the study of the animal organisation by that of man, we do not therefore follow the analytic method; we do not proceed from what is simple to what is more complex. It would perhaps be an easier and a more natural way of arriving at a solution of the grand and difficult problem of the animal economy, to begin by explaining its most simple terms; to rise by degrees from plants to vegetating animals, as polypi; from these to white-blooded animals; then to fishes and reptiles; from the latter to warm-blooded animals; and, lastly, to man himself, placed at the head of that long series of being, whose existence becomes complicated in proportion as they approach him.

The study of every part of natural history, and especially of comparative anatomy, cannot fail, therefore, to prove of infinite advantage to the physiologist; a truth well expressed by the eloquent M. de Buffon,* who says, that if there existed no animals, the nature of man would be still more incomprehensible.

I shall say nothing of the well-known relations of physiology to medical science, of which it is justly considered as the base or support. Medicine, called by some the art of healing, by others, more properly, the art of treating diseases, may be defined the art of preserving health, of curing diseases, or of rendering them more supportable; medicine, in all its parts, is enlightened by physiology, and cannot have a surer guide. Owing to a neglect of this auspicious guide, therapeutics and materia medica long remained involved in a mist of conjectures and hypotheses. Physicians

worlds, embracing all the spheres, should extend from the atom to the most exalted of cherubim, is noble and interesting. Without carrying it so high or so low, if we confine it to the natural beings with which we are well acquainted, and which can be brought under observation, it will be seen, that the idea is not so chimerical as some writers of most respectable authority have supposed it. The plan traced by C. Bonnet is evidently defective; we find in it beings set beside each other, that have but faint lines of resemblance, or altogether illusive. The present state of the natural sciences would allow of its being better done: one might try at least for all bodies what Jussieu has executed with regard to vegetable productions; and if this undertaking, in the hands of men the most able to bring it to a successful termination, left any thing defective, would not that imperfection be an indication of the existence of other worlds, or of lands yet unknown on the globe we inhabit; undiscovered regions, where those animals, and plants, and minerals, would be found which were wanting to fill up the gaps in the immense series of co-ordinate existence?

Demonstratum fuit et hoc, nullam rem contrarias, vel omninò, multùm differentes, qualitates recipere posse, nisi per medias priùs iter fecerit.—GALENUS *de Usu Partium*, lib. iv. cap. 12.

* Histoire Nat. tom. v. 12mo. p. 241. Discours sur la Nature des Animaux.

should never for a moment forget, that as a great number* of diseases consist in a derangement of the vital functions, all their efforts should tend to bring back sensibility and contractility to their natural condition; that the best classification of diseases and of medicines is that which is founded on a judicious distinction of the vital powers. With this view it is that M. Alibert, in his elements of materia medica, classes medicines according to their effects on sensibility or contractility, and according to the organs on which their action is particularly exerted.

Sect. XII.—CLASSIFICATION OF THE VITAL FUNCTIONS.

After having treated separately of the vital powers or faculties, nothing is easier than to arrange, in a clear and methodical order, the functions carried on by the organs which these powers call into action. The term *function* might be defined *means of existence.* This definition would be the more just, as life is only the exercise of these functions, and as it ceases when any one of the more important can no longer be carried on. From not distinguishing the faculties from the functions, which are merely the acts of the faculties or powers, several modern divisions, though far preferable to the old classification of the functions into vital, animal, and natural, are, nevertheless, deficient in accuracy and simplicity. Thus, Vicq-d'Azyr, in the classification of the phenomena of physiology, inserted in the discourse which he has prefixed to his work on anatomy, mistakes the cause for the effect, and places sensibility and irritability among the functions; and commits another mistake, by ranking ossification among the latter, which is but a peculiar mode of nutrition, belonging to parts of a hard structure.

The best method of classing the actions which are performed in the living human body is, doubtless, that by which they are distributed and arranged according to the object which they fulfil. Aristotle, Buffon, and especially Grimaud, have laid on that base the foundation of a method which we shall adopt, with the modifications which we are about to mention.

Aristotle and Buffon had observed, that among the acts of the living economy, some were common to all beings that have life, to plants and animals during sleep and in waking, while others seemed to belong exclusively to man, and to the animals which more or less resemble him. Of these two modes of existence, the one *vegetative*, the other *animal*, the former appeared to them the more essential, as being more diffused, and consisting merely in the assimilation of nutritive molecules in the nutrition absolutely necessary to the preservation of the living being,† who, as his substance is incessantly wasting, would soon cease to exist, if these continual losses were not always repaired by the act of nutrition.

Grimaud, Professor of Physiology at Montpellier, too soon lost to the science which he cultivated as a philosopher, truly deserving that name, adopted this simple and luminous division, developed it better than had been done before him, and uniformly followed it in his lectures and in his works.‡ The division of the functions into *internal*, which he likewise

* All diseases consist in *physical derangements*, as solutions of continuity, displacements; *organic alterations*, as polypi, aneurisms, and other affections resulting from organic affection and alteration of structure; *vital lesions*, as sthenic, asthenic, ataxic disorders, asphyxia, &c.—See *Nosographie et Thérapeutique Chirurgicales*, 5° edit. Paris, 1821; *Prolégomènes*, tom. i.

† *Nam anima* nutritiva *etiam aliis inest, et prima et maxima communis facultas animæ, secundùm quam omnibus vivere inest.*—Aristot. *de Anim.* lib. ii. cap. 4.

‡ In his MS. lectures on physiology, he seems to feel a complacency in that division which he had in a manner appropriated to him-

calls *digestive*, and into external or locomotive, lately brought forward under the name of *organic* and *animal*,—the former of which terms is quite inaccurate and defective, since it leads to a belief that the animal life or that of relation is not confided to organs, and that the vital instruments are solely employed on internal life or of nutrition (*Motus assimilationis*, Bacon; *Blas alterativum*, Van Helmont)—this division does not comprehend the whole of the phenomena, and does not embrace the sum of the functions which are performed in the animal economy. In fact, there are not found in the two great classes which it establishes, the acts by which animals and vegetables reproduce and perpetuate themselves, and immortalise the duration of their species. All the functions destined to the preservation of the species are not included; they merely relate to the functions subservient to the preservation of individuals.

I have, therefore, thought it right to include under two general classes: 1, the functions which tend to the preservation of the individual, and enable him to enjoy an isolated mode of existence; 2, the functions which belong to the preservation of the species, functions without which man might exist, as we see in eunuchs, but without which the human species would soon perish, from a loss of the power of reproduction. In laying down these two great divisions, I have merely considered the object and end which each function has to fulfil.

Among the functions which are employed in the preservation of the individual, some fulfil this office by assimilating to his own substance the food with which he is nourished; the others, by establishing, in a manner suited to his existence, his relations with the beings which surround him.

The fuctions destined to the preservation of the species, may likewise be divided into two classes. Those of the first class require the concourse of two sexes; they constitute generation, properly so called: those of the second order, exclusively belong to the female, who, after conception, is alone destined to bear, to nourish, to bring into the world, and suckle the new being, the result of conception.*

The internal, assimilating, or nutritive functions concur in the same end, and all serve to the elaboration of the nutritive matter. The aliment once admitted into the body is subjected to the action of the digestive organs, which separate its nutritive parts; the absorbents take it up, and convey it into the mass of fluids; the circulatory system conveys it to all the parts of the body, and makes it flow towards the organs; the lungs and the secretory glands supply it with certain elements, and deprive it of others, alter, modify, and animalise it: in fine, nutrition, which may be considered

self, by his happy illustrations of it, and by the changes which he had introduced into it. In every lecture, I might almost say in every page, he returns to this division, explains it, dilates, and comments upon it. "The functions," says he, "may be divided into two "great classes; some are formed in the interior of the body, and exclusively belong to "it; others take place outwardly, and belong "to external objects," &c. The digestive power presides, in his opinion, over the *internal functions*, whose object is *nutrition*; the locomotive power directs the external functions. "It is by means of the organs of sense that the animal enlarges his existence, that he applies and distributes it to the surrounding objects, and takes cognizance of the qualities in those objects which concern him; it is by means of the muscles essentially obedient to the organs of sense, that he adapts himself to those objects, that he places himself in a manner suited to the mode of their activity," &c.

* The classification of the functions which Richerand has adopted, with a slight modification, from Grimaud, nearly agrees with the one more generally followed by the best modern physiologists. Sprengel arranges them into the *vegetative*, the *sensiferous*, and the *generative*. Cuvier forms but two classes, the *vital* and *animal*. Magendie and Adelon divide them into *functions of relation*, *functions of nutrition*, and *functions of generation*. Lenhossek, professor of anatomy and physiology in the university of Vienna, classes the functions into those of *organic life*, of *sensiferous or animal life*, and those belonging to *generation*. Dr. Bostock admits only two classes, the *contractile* and *sensitive*.—*J. C.*

as the complement of assimilating functions, whose object it is to provide for the maintenance and growth of the organs, applies to them this animalised substance, assimilated by successive acts, when it has become quite similar to them.

Several, however, of these functions serve at once to preserve and to destroy: absorption, which takes up extraneous molecules, to be employed in the growth of the organs, takes up equally the organic molecules which are detached by motion, friction, heat, and all the other physical, chemical, and vital causes: the action of the heart and of the blood-vessels sends these fragments, together with the parts truly recrementitious, towards the lungs, which, at the same time that they bring about a combination of the nutritive parts with the oxygen of the atmosphere, separate from the blood the materials which can no longer be employed in nourishing the organs; the same power propels them towards the secretory glands, which not only purify what is liquid, by separating from it that which cannot without danger remain in the animal economy, but which likewise elaborate or prepare peculiar fluids, some of which are results of the act of nutrition, are employed in that act, and impart to the substances on which it is performed a certain degree of animalisation (as to the bile and saliva), while the others seem to be intermediate states, which the nutritive particles of the food are obliged to undergo, before complete animalisation; such are the serous fluids and the fat.

It might perhaps seem more in conformity to the order of nature, to have combined the account of respiration with that of the circulation, by treating of the course of the venous blood, after the action of the absorbent vessels, with which the veins have so much analogy;—then to have treated of the phenomena of respiration, or of the conversion of the venous blood into arterial, and of the course of the latter into all the parts of the body by the action of the heart and arteries; but the advantage which would be obtained from a method so contrary to the common practice, which is to consider separately the functions of circulation and respiration, appeared to me too unimportant to justify its adoption.

The external or relative functions, equally connected by their common destination, associate the individual to every thing that surrounds him: the sensations, by warning him of the presence of objects which may be useful or injurious to him; motion, by enabling him to approach or avoid such objects, according as he perceives relations of advantage or disadvantage, according as the opposite sensations of pain or pleasure result from his action on them, or from theirs on him. In fine, voice and speech give him communication with beings enjoying the same means of communication, and that without a necessity of motion. The brain is the principal organ of these functions, as the system of circulation is the centre of the assimilating functions. All the impressions received by the organs of sense are transmitted to the brain, and from the brain determinations arise, as well as the voluntary motions and the voice. The sanguineous system receives the molecules destined to nutrition, and those which are to be thrown out of the body. The sensitive and circulatory systems are the only systems provided with a centre (the brain and the heart), which extend to all parts of the body, by emanations originating from that organ, or terminating in it (the nerves, the arteries, and veins): and as the motions and the voice depend on sensation, and are immediately connected with it as necessary results, so respiration, secretion, and nutrition, are, in a manner, but consequences of the circulation which distributes the blood to all the organs, in order that these may produce on it various changes, which constitute respiration, secretion, and nutrition. They are, if I may anticipate what

is to come hereafter, only different kinds of secretion that take place at the expense of the different principles contained in the blood.

The circulation, which holds the functions of nutrition in a kind of dependence, subjects the brain, which is the principal organ of the external functions, to an influence still more immediate and indispensable. The muscular motions are not less under its influence. It is the first function that is apparent in the embryo, whose evolution it brings about: in natural death, of all the functions, it is the last to cease. These reasons justify Haller for having placed the circulation in the first order, and for having begun by its history his great work on physiology. I enter into this digression only to expose the absurdity of the claims of some authors, who, because they have varied the methodical order of the functions, broken the series, or made the slightest changes,—for example, by placing the history of the functions of smell and taste before the account of the internal or nutritive functions,—think they have totally changed the aspect of the science: pitiful sophists, who accumulate subtleties instead of facts and ideas.

In warm and red-blooded animals, the nutritive functions, digestion, absorption, circulation, respiration, the secretions, and digestion, are performed as in man, and in that respect there exist between them very slight differences: nay, in some animals, these functions are performed with much more energy. Thus several animals digest substances on which our own organs produce no effect, and others (birds) have a more rapid circulation, a more active nutrition, and evolve more heat. But not one of them is as well provided with organs to keep up intercourse, as a living being, with the surrounding objects. In no one animal are the senses possessed of the same degree of perfection; the eagle, whose sight is so piercing, has a very dull sense of touch, taste, and smell. The dog, whose smell is exquisite, has a very ordinary extent of sight: in him the taste and touch are equally imperfect—his touch, in the perfection of which no animal comes up to man, has not been improved in delicacy, at the expense of the other senses. The sight, the hearing, the taste and smell, preserve a great delicacy, when their sensibility has not been impaired by injudicious or too frequent impressions. The sensitive centre is in no one better developed, and fitter to direct safely the use of the organs of motion. No other animal can articulate vocal sounds, so as to acquire speech.

This greater extension of life in man, from the number and perfection of his organs, makes him liable to many more diseases than the other animals. It is with the human body as with those machines, which become more liable to be deranged, by increasing the number of their wheels, with a view of obtaining more extensive or more varied effects.

All organised bodies are possessed of assimilating functions; but as assimilation requires means varying in number and power, according to the nature of the being which performs it. The series of assimilating phenomena commences in the plant by absorption, since it draws immediately from the earth, the juices which it is to appropriate to itself. Its absorbing system at the same time performs the functions of a circulatory organ, or rather the circulation does not exist in plants; and the direct and progressive motion of the sap, which ascends from the root towards the branches, and sometimes in a retrograde course from the branches towards the roots, cannot be compared to the circulation of the fluids which takes place in man, and in the animals which most resemble him, by means of a system of vessels which every moment bring back the fluids to the same spot, and convey them over the whole body, by making them describe a complete circle, frequently even a double rotation, (animals with a single or double circulation, that is, whose

heart has one or two ventricles). Plants breathe after their own manner, and produce a change in the atmospherical air, by depriving it of its carbonic acid gas, the result of combustion and of animal respiration : so that, by a truly admirable reciprocity, plants which decompose carbonic acid, and allow oxygen to exhale, continually purify the air, which combustion and animal respiration are incessantly contaminating.*

The functions preservative of the species are common to animals and plants. The organs by which these functions are performed, when compared in these two kingdoms of nature, offer a resemblance which has struck all naturalists, and has led them to observe, that of all the acts of vegetable life, no one is more analogous to the animal economy than that by which fecundation is effected.

I shall not here explain the general characters of the two orders of functions which are subservient to the preservation of the species : the differences which belong to them are pointed out in several parts of this work.† I shall merely observe, with the authors who have considered them generally, that they are in an inverse ratio to each other ; so that, in proportion as the activity of the assimilating functions increases, that of the external functions is abated. Grimaud has, in the most complete manner, illustrated this idea of the constant opposition which exists between those two series of actions, over which, in the opinion of that physician, there preside two powers, which he calls locomotive and digestive. It is in no kind of animals more distinct than in the carnivorous, which possess organs of sense of the greatest delicacy, together with muscles capable of prodigious efforts, and yet powers of assimilation so feeble that their food cannot be digested, unless it be composed of materials analogous in composition to their own organs.‡

Too much importance should not be attached to this classification ; like all other divisions, it is purely hypothetical. All is connected together, all is co-ordinate in the animal economy ; the functions are linked together, and depend on one another, and are performed simultaneously ; all represent a circle of which it is not possible to mark the beginning or the end. *In circulum abeunt* (Hippocrates). In man, while awake, digestion, absorption, circulation, respiration, secretion, nutrition, sensation, motion, voice, and even generation, may be performed at the same time ; but whoever, in the study of the animal economy, should bestow his attention on this simultaneous exertion of the functions, would acquire but a very confused knowledge of them.§

* This opinion originated with Priestley, and was generally adopted, in opposition to the experience of his contemporary, the celebrated Scheele. More modern physiologists, especially Ellis, Gilby, and T. de Saussure, have shewn, by well-conducted experiments, that all plants, whether growing in absolute darkness, in the shade, or when *not* exposed to the direct rays of the sun, "are constantly removing a quantity of oxygen from the atmosphere, and substituting an equal volume of carbonic acid." Thus far these philosophers nearly agree. They differ, however, very widely respecting the manner in which this change is effected. Ellis supposes that the leaves, flowers, fruits, stems, and roots of plants emit carbonaceous matter, which combines with the oxygen of the surrounding air. Gilby and Saussure are of opinion that the oxygen is absorbed by the respiratory organs, and that the carbonic acid is formed within the plant.

Although vegetables, under the ordinary circumstances of their growth, consume oxygen during respiration, and disengage carbonic acid, yet, according as their situation and particular condition may require, they partially absorb the carbonic acid from the air, convert it to their use, decompose it, and emit the oxygen which results from the decomposition, especially when they are exposed to the sun's rays. The illustration of this subject belongs to vegetable physiology.—*J. C.*

† Especially in the account of living beings, Sect. V. of the Preliminary Discourse, articles *sleep* and *fœtus*. It is impossible at present to go over all these distinctions, without entering into useless and disagreeable repetitions.

‡ In carnivorous animals the power of digestion is exceedingly weak, but their muscles are very powerful. This relative force of the muscles was necessary in carnivorous animals, as they live by depredations and slaughter, as their instinct, in unison with their organisation, sets them constantly at war with every thing that has life, and as their subsistence depends on their being victorious in their battles to which nature incessantly calls them.—GRIMAUD, *first Memoir on Nutrition.*

§ The division which I lay down is not to be strictly adopted, and as being absolutely true.

By becoming familiar with these abstractions, one might soon mistake them for realities, and even go the length of seeing two distinct lives in the same individual; one would be apt to assign, as the character of internal life, that it is carried on by organs independent of the will, although this faculty of the mind presides over the phenomena of respiration, of mastication, and of the expulsion of the urine and fæces; one might consider life as intrusted to *unsymmetrical* organs, although the heart, the lungs, and the kidneys, are evidently symmetrical; and might fancy it to exist in the fœtus, which neither breathes nor digests, &c. Nothing in the animal economy, said Galen, is ruled by invariable laws, or can be subject to the same accurate results and calculations as an inanimate machine. (*Nil est in corpore viventi planè sincerum.* Galen.) Thus respiration, which connects the external and assimilating functions, furnishes the blood with the principle which is to keep up the action of the brain, and to excite muscular contractions. On the other hand, the motion of the muscles is of use in the distribution of the humours, and concurs in the phenomena of assimilation. The brain, by means of the eighth pair of nerves, holds influence over the stomach. The sensations of taste and smell seem to preside in an especial manner over the choice of food and of air, and to belong rather to the digestive and respiratory functions than to those of the intellect or of thought.

We have seen in this kind of general introduction of the study of physiology what idea is to be formed of that science as well as of life, the study of which is its object; into how many classes the beings in nature may be divided, and into how many elements they are resolvable; what differences exist between inorganised and organised and living bodies, between plants and animals; how life is complicated, modified, and extended, in the immense series of beings which are endowed with it, from the plant to man; and in further particularising the object under our consideration, we have examined what are the organs which, by their union, form the human machine; what powers govern the exercise of their functions. Then we have laid down the fundamental laws of sensibility and contractility; we have spoken of sympathies and habits; of the internal nervous apparatus, which unites, collects, and systematises the organs of the assimilating functions; we have endeavoured to determine from facts the existence of the cause which subjects living beings to a set of laws very different from those which inorganic matter obeys. The knowledge of these laws is the light which is to guide us in the application to physiology of the accessory sciences. Finally, in the arrangement of the objects which this science considers, I have adopted a more simple and natural division than any hitherto employed.

I shall close this Preliminary Discourse by saying a few words on the order adopted in the distribution of the chapters. I might have begun by a view of the external functions, as well as of those of assimilation or nutrition, of sensation, or of digestion. I have given preference to the functions of assimilation, because of all others they are the most essential to existence, and their exercise is never interrupted from the instant in which the embryo begins to live till death. In beginning with an account of them, we imitate

It is a mere hypothesis, to be attended to only in so far as it assists in arranging one's ideas in a more orderly manner. For every arrangement, even when arbitrary, is useful in laying before us a great number of ideas, and in thereby facilitating the comparison that is to be instituted among them. All the acts of Nature are so connected, and are linked together in so close a union, and she passes from the one to the other by such uniform motions, and by gradations so insensible and so adjusted, as to leave no space for us to lay down the lines of separation or demarcation, which we may choose to draw. All our methods of classing and arranging the productions of nature are mere abstractions of the mind, which does not consider things as they really are, but which attends to certain qualities, and neglects or rejects all the rest.—GRIMAUD, *Lectures on Physiology.*

nature, therefore, who imparts to man this mode of existence before she has connected him with outward objects, and who does not deprive him of it until the organs of sense, of motion, and of the voice, have completely ceased to act.

As to the course which has been followed in the arrangement of the functions that belong to the same order, or which concur in the same end, it was too well laid down by nature to allow us to depart from it. I have thought it right that the consideration of the voice should immediately precede that of generation, in order that the arrangement might, at a glance, shew the connexion which exists between their phenomena. Several animals use their voice only during the season of love: the birds which sing at all times, have, during that period, a more powerful and sonorous voice. When man becomes capable of reproduction, his vocal organs suddenly become evolved, as though nature had wished to inform him that it is through them he is to express his desires to the gentle being who may sympathise in them. The voice, therefore, serves as a natural connexion between the external functions and those which are employed in the preservation of the human species.

The voice, which leads so naturally from the functions which establish our external relations to those whose end is the preservation of the species, is still more intimately connected with motion. It is, in a manner, the complement of the phenomena of locomotion; by means of it our communication with external objects is rendered easier, more prompt, and more extensive: it depends on muscular action, and is the result of voluntary motion. Finally, these motions sometimes supply the place of speech—in pantomime, for example; and in the greater number of cases the language of action concurs in adding to its effect. Every thing, therefore, justifies me in placing this function after motion, in separating it from respiration, with which every other author has joined it, without considering that the relation between the voice and respiration is purely anatomical, and can therefore in no wise apply to physiology.

I have placed after generation an abridged account of life and death, in which will be found whatever did not belong to any of the preceding divisions. The necessity of this Appendix, containing the history of the different periods of life, that of the temperaments and varieties of the human species, that of death and putrefaction, arises from the impossibility of introducing into the particular history of the functions these general phenomena in which they all participate.

TABLE OF THE CLASSIFICATION OF THE FUNCTIONS OF LIFE.

Class	Order	Genus	Functions
CLASS I. FUNCTIONS WHICH TEND TO THE PRESERVATION OF THE INDIVIDUAL. (*Individual Life.*)	ORDER I. Those which assimilate with the Structures the Alimentary Substances. (*Nutritive, assimilating, or interior Functions.*)	Genus I.—Digestion. *In extracting the nutritive Parts of our Food.*	Seizing the Food.—Mastication.—Insalivation.—Deglutition. Chymification.—Chylifaction.—Absorption of Chyle.—Excretion of fæcal Matters, and of the Urine.
		Genus II.—Absorption. *In transporting nutritious Matter into the Current of the Fluids.*	The Action of the Vessels.—Action of the Lymphatic Glands.—Action of the Thoracic Duct.
		Genus III.—Circulation. *In conveying the Fluids to all the Organs.*	The Action of the Heart.—Action of the Arteries.—Action of the Capillary Vessels.—Function of the Veins.
		Genus IV.—Respiration. *In combining with the Oxygen of the Air.*	Action of the Parietes of the Thorax.—Action of the Lungs.—The Changes effected on the Air.—Changes produced on the Blood.—Calorification or Animal Heat.
		Genus V.—Secretion. *In producing different Changes on the Fluids.*	Cutaneous, Pulmonary, and Serous Transpiration.—The Secretion from Mucous Follicles.—Secretion from Glands.
		Genus VI.—Nutrition. *In increasing the Bulk and supplying the Waste of the Organs.*	Different in each Part, according to its peculiar Constitution.
	ORDER II. Those Functions which hold Relation with surrounding Objects. (*Exterior or relative Functions.*)	Genus I.—Sensations. *In giving notice of their Presence.*	Organs of Seeing, or Hearing, of Smell, of Taste, of Touch.—Action of the Nerves; of the Spinal Chord; of the Brain.—Sensation. Memory. Judgment. Reasoning. Volition. Sleep and Waking. Dreaming and Somnambulism.
		Genus II.—Voluntary Motions. *In approaching or receding.*	Muscular Organs and Actions.—The Skeleton.—The Joints.—Standing.—The progressive Movements of Walking, Running, Leaping, Swimming, Flying, Creeping.—Movements of the superior Extremities.—Attitudes.—Gesticulation.
		Genus III.—Voice and Speech. *In communicating with Creatures provided with the Organs of Hearing, without the necessity of changing Place.*	Articulate Voice or Speech.—Modulated Voice, or Singing.—Stammering.—Lisping.—Dumbness, &c.
CLASS II. FUNCTIONS WHICH ARE SUBSERVIENT TO THE PRESERVATION OF THE SPECIES (*Life of the Species.*) *Reproductive Functions. Functions of Reproduction.*	ORDER I. Those which appertain to both Sexes.	Generation	General Differences of the Sexes.—Hermaphrodism.—Systems of Generation.
	ORDER II. Functions exclusively belonging to the Female.	Genus I.—Gestation	State of the Uterus after Impregnation.—History of the Embryo; of the Fœtus; of its Envelopes.—Acephalous and other monstrous Fœtuses.
		Genus II.—Parturition	Of the Uterus during and after Parturition.—The Lochia.
		Genus III.—Lactation	Function of the Breasts.—The Milk.

Periods of Growth	Infancy.—Dentition.—Ossification. Puberty.—Menstruation. Youth.	
Manhood	*Temperament*	Sanguine.—Muscular.—Bilious.—Melancholy.—Lymphatic.—Nervous.
	Idiosyncrasies.	
	Races of the Human Species	Arabo-European.—Mongolian.—Negro.—American.—Hyperborean.
Periods of Decline	Turn of Life. Old Age. Decrepitude.	

Death.
Putrefaction.

FIRST CLASS.

THOSE FUNCTIONS WHICH TEND TO PRESERVE THE INDIVIDUAL.

First Order.

FUNCTIONS OF ASSIMILATION;

OR,

FUNCTIONS WHICH ARE SUBSERVIENT TO THE PRESERVATION OF THE INDIVIDUAL, BY ASSIMILATING TO HIS SUBSTANCE THE FOOD BY WHICH HE IS NOURISHED.

CHAPTER I.

OF DIGESTION.

I. Definition of Digestion.—II. General considerations on the Digestive Organs.—III. Of Food, solid and liquid.—IV. Of Hunger.—V. Of Thirst.—VI. to IX. Of Mastication.—X. and XI. Of Salivary Solution.—XII. Of Deglutition.—XIII. Of the Abdomen.—XIV. to XIX. Of Digestion in the Stomach: various opinions respecting this process.—XX. to XXII. Of the Gastric Juice.—XXIII. Of the Uses of the Pylorus.—XXIV. Of Vomiting.—XXV. Of Digestion in the Duodenum.—XXVI. Of the Bile, and Biliary Apparatus.—XXVII. Of the Uses of the Bile.—XXVIII. Of the Actions of the small Intestines.—XXIX. Of the Functions of the large Intestines.—XXX. Of Fæcation and Fæcal Evacuation.—XXXI. to XXXV. Of the Secretion and Excretion of the Urine.—XXXVI. Of the Physical Properties of the Urine.—XXXVII. and XXXVIII. Of the Chemical Properties of the Urine.—XXXIX. Of various States of the Urine.

I. Digestion is a function common to all animals, by which substances extraneous to them are introduced into their body, and subjected to the action of a peculiar system of organs, their qualities altered, and a new compound formed, fitted to their nourishment and growth.

II. *General considerations on the Digestive Organs.*—Animals alone are provided with organs of digestion; all of them, from man down to the polypus, contain an alimentary cavity, variously shaped. The existence of a digestive apparatus may, therefore, be taken as the essential characteristic of the animal kind. In man this apparatus consists of a long tube, extending from the mouth to the anus; within this canal there empty themselves the excretory ducts of several neighbouring glands, that secrete fluids fit for changing, for liquefying, and animalising the alimentary substance. The different parts of this digestive tube are not of equal capacity; at first, enlarged in the part which forms the mouth and pharynx, it becomes narrower in the œsophagus; this last, dilating considerably, forms the stomach, which again contracting, is continued down under the name of intestine. The tube itself varies in size in different parts of its extent; and it is by the consideration of these differences of size, that anatomists have principally been guided in their divisions.

The length of the digestive tube is from five to six times the length of the whole body in an adult: it is greater in proportion in a child. At this age, likewise, digestion is more active, and proportioned to the necessities of growth in the individual. The digestive cavity is in man open at both extremities: in some animals, in the zoophyte for example, one opening serves the purpose of mouth and of anus, receives the food, and ejects the excrementitious remains.

The extent of the digestive canal is according to the nature of the aliments on which the animals feed: the less those aliments are analogous in their nature to the substance of the animal which they are to nourish, the longer must they remain in his body to undergo the necessary changes. Therefore, it is observed, that the intestine of graminivorous animals is very long, their stomach very capacious, and often complex, while carnivorous animals have their intestinal canal short and strait, and so arranged, that the animal substances which are most nourishing, in least bulk, of easy and rapid digestion, and which, by too long a stay in the intestines might become putrid, pass readily through it. In this respect man holds a middle station between those animals which feed on vegetables, and those which feed on animal substances. He is, therefore, equally fitted for these two kinds of food; he is neither ex-

clusively herbivorous nor carnivorous, but omnivorous, or *polyphagous*. This question, of such easy solution, has long employed physicians, naturalists, and philosophers; each bringing, in favour of his opinion, very plausible arguments, drawn from the form and number of the teeth, from the length of the intestinal canal, from the force of its parietes, &c.

The parietes of the digestive tube are essentially muscular; a mucous membrane lines its inside, forming within it various folds; lastly, a third coat is accidentally placed over the other two, and is furnished by the pleura to the œsophagus, and by the peritoneum to the stomach, as well as to the intestinal canal.

The characteristic of this third coat is, that it does not cover the whole surface of the parts of the tube to which it is applied. The muscular coat may be considered as a long hollow muscle, extending from the mouth to the anus, and formed, throughout almost the whole of its length, by two layers of fibres; the one set longitudinal, the other circular. The will directs the motions of the two extremities, while the rest of its course is not under its control. In the cells of the tissue which unites its surfaces to the other coats, fat never accumulates, which might have impeded its contractions, and straitened, and even obliterated, the tube along which the food was to pass.*

III. *Of food, solid and liquid.*—The aliments which nourish man are obtained from vegetables or from animals. The mineral kingdom furnishes only condiments, medicinal substances, or poisons.†

By aliment is meant whatever substance affords nutrition, or whatever is capable of being acted upon by the organs of digestion. Substances which resist the digestive action, those which the gastric juice cannot sheathe, whose asperities it cannot soften down, whose nature it cannot change, possess, to a certain degree, the power of disturbing the action of the digestive tube, which revolts from whatever it cannot overcome: there is no essential difference between a medicinal substance and a poison. Our most active remedies are obtained from among the poisonous substances: tartar emetic, corrosive sublimate, opium—all of them remedies of so much efficacy in skilful hands—when administered unseasonably, or in too strong doses, act as most violent poisons: they forcibly resist the digestive powers, and furnish them nothing to be acted upon, while mild and inert substances yield to these powers, and come under the class of aliments. What then is to be thought of our ptisans, of chicken and veal broth, and other such remedies? That they are employed to deceive the hunger and thirst of the patient, to prevent his receiving into his stomach substances whose laborious digestion would exhaust the strength required for the cure of the disease; that they are mere

* The digestive tube comprehends: 1, the mouth: 2, the pharynx; 3, the œsophagus; 4, the stomach; 5, the small intestines; 6, the large intestines; and, 7, the anus. The commencement and termination of this apparatus are subjected, but not completely, to the influence of the will. Volition and sensation are distinctly evinced in the mouth and pharynx: in the œsophagus and stomach the influence of the will gradually disappears, and sensation becomes imperfect and peculiar. It is in consequence of the distribution of voluntary nerves, in greater or less number, to the extremities of the alimentary canal, and of the accession of their influence to the ganglial system of nerves which chiefly supply the digestive apparatus, that many of the sensations and operations which belong to its upper portion, as the pharynx, œsophagus, and the stomach, are so peculiar, and so difficult of explanation.—*J. C.*

† Magendie arranges the aliments which nourish man according to the immediate principle which predominates in their composition. After this manner he distinguishes nine classes; namely, farinaceous, mucilaginous, saccharine, acidulated, oleaginous, milky or cheesy, gelatinous, albuminous, and fibrinous aliments. Dr. Prout, in the paper which lately obtained the Copleyan Medal of the Royal Society, considers that the food of the higher animals may be arranged in three classes: the saccharine, the oily, and the albuminous. The first consists of sugars, starches, gums, acetic acid, and some other analogous substances; the second, of oils, fats, alcohol, &c.; the third, of other animal matters, and vegetable gluten, which abounds in wheat.—*J. C.*

precautions of regimen; and that he who most varies this kind of resource, can only be said to adopt a treatment of expectation, leaving to nature alone the care of exciting those salutary motions which are to bring about a cure. Why do certain vegetable purgatives, as manna and tamarinds, produce so little effect, even though given in large doses? Because these substances contain many nutritious particles capable of being assimilated, so that strong constitutions digest them, and completely neutralise their irritating or purgative qualities. An animal or vegetable substance, though essentially nutritious, may act as a medicine, or even as a poison, when, in consequence of the extreme debility of the digestive tube, or because it has not been sufficiently divided by the organs of mastication, it resists the digestive action. Thus surfeits are brought on, because the stomach is debilitated, because it is oppressed by too great a mass of substances, or because, having been imperfectly triturated, they are insoluble. It is on considerations of this kind that the true foundations of materia medica are laid.

Mineral substances are of a nature too heterogeneous to our own to admit of being converted into our substance. It appears that their elements require the elaboration of vegetable life; hence it has been justly observed, that plants are laboratories in which nature prepares the food of animals.

Aliments obtained from plants are less nutritious than those furnished by the animal kingdom, because in a given bulk they contain fewer parts than can be assimilated to our own substance. Of all the parts of vegetables, the most nourishing is their amylaceous fæcula; but it yields the more readily to the action of the digestive organs from having already experienced an incipient fermentation; on that account leavened bread is the best of vegetable aliments. The flesh of young animals is less nourishing than that of the full-grown, although, at an early age, the flesh of the former abounds more in gelatinous juices; for this abundant gelatine is also much more watery.

However various our aliments may be, the action of our organs always separates from them the same nutritious principles: in fact, whether we live exclusively on animal or vegetable substances, the internal composition of our organs does not alter; an evident proof, that the substance which we obtain from aliments to incorporate with our own, is always the same; and this affords an explanation of the saying of the father of physic, "There is but one food, but there exist several forms of food."

Attempts have been made to ascertain the nature of this alimentary principle, common to all nutritive substances, and it is conjectured, with some probability, that it must be analogous to gummy, mucilaginous, or saccharine substances: they are all formed from hydrogen and carbon; and are well known to differ chemically only in the different proportions of oxygen which they contain. This sugar is a kind of gum, containing a considerable quantity of oxygen, and which is reduced, in a certain degree, to a state of starch, when brought to a very fine powder by means of a rasp; for the friction, disengaging a portion of its oxygen, deprives it in part of its flavour, and leaves it an insipid taste, similar to that of farinaceous substances. Nothing, in fact, nourishes better, more quickly, and from a smaller bulk, than substances of this kind. The Arab crosses the vast plains of the desert, and supports himself by swallowing a small quantity of gum arabic. The nourishing quality of animal and vegetable jellies is well known; saccharine substances soon cloy the appetite of those who are fondest of them. In decrepit old age, some persons live exclusively on sugar: I know several in that condition, who spend the day in chewing this substance, which is a laborious employment for their feeble and toothless jaws.* Lastly, milk, the

* Magendie concluded, from his experiments, that no animal seems capable of deriving nutri-

sole nourishment of the early periods of life, contains a great proportion of gelatinous and saccharine matter.

Though man, destined to live in all latitudes, is formed to subsist on all kinds of food, it has been observed that the inhabitants of warm climates generally prefer a vegetable diet.* The Bramins in India, the inhabitants of the Canary Islands, and of the Brazils, &c. who live almost exclusively on herbs, grain, and roots, inhabit a climate against the excessive heat of which they have to seek means of protection; now, the digestion of vegetables is attended with less heat and irritation. The philosophical or religious sects, by which the abstinence from animal food was considered as a meritorious act, were all instituted in warm climates. The school of Pythagoras flourished in Greece; and the anchorets, who in the beginning of the Christian religion peopled the solitudes of Thebais, could not have endured such long fastings, or supported themselves on dates and water, in a more severe climate; so that the monks that removed into different parts of Europe were obliged to relax from the excessive severity of such a regimen, and yielded to their resistible influence of the climate: thus, the most austere were induced to add to vegetables, which formed the base of their food, eggs, butter, fish, and even water-fowl. In books of casuistry it may be seen on what ridiculous grounds there was granted a dispensation in favour of plovers, of water hens, wild ducks, snipes, and scoters; birds whose brown flesh, more animalised and more heating, ought to have been proscribed from the kitchens of monasteries much more strictly than that of common poultry.

Consider what is the alimentary regimen of the different nations on the face of the earth, and you will see that a vegetable diet is preferred by the inhabitants of warm countries: to them sobriety is an easy virtue; it is a

ment from any substance that does not contain some portion of azote. There are, however, many circumstances which prove the contrary. Adanson asserts, that the Nomadic Moors have scarcely any other food than gum senega. Hasselquist relates, that a caravan of Abyssinians, consisting of 1000 persons, subsisted for two months on a stock of gum arabic alone, which they found among their merchandise; and it is well known, that negroes, and individuals otherwise imperfectly fed, soon become fat from the mastication of the sugar-cane. A case, which fully exemplifies the nutritious quality of sugar, lately came under our observation, in a lady, about the middle age, who consulted us respecting great and increasing corpulency. Her countenance was full, clear, and florid; her pulse strong; her health excellent; and her strength very considerable. She partook of animal food only once in a day, and then in a very small quantity. She never took suppers, and was very moderate in the use of fluids. She had always taken considerable exercise on foot, and even up to the period at which we saw her, she resorted to it as much as the great bulk of her body could permit. The secret, however, of her increasing obesity was disclosed, when she mentioned her insatiable desire for refined sugar, which she almost hourly made use of, frequently to the extent of one pound weight daily. She considered it her chief article of diet. She reckoned the average quantity which she used at about three-fourths of a pound in the day. Tea or coffee was taken by her sweetened in the usual way. She ate the sugar in the solid state, and unaccompanied with any other article of diet; the finest sort only was relished. Her digestive functions were in a perfect condition; neither cardialgia, acidity, nor flatulence, were complained of. Her teeth were sound. She found her corpulence supervene to a spare habit of body, some time after the practice of eating sugar was acquired. She thought that the obesity increased with the increase in the quantity of sugar which she consumed. The habit had become so confirmed, at the time when we saw her, that she conceived it to be quite impossible to relinquish it.—*J. C.*

* The inhabitants of warm climates, who are subjected, in consequence of the nature of the situation in which they live, to a moist and miasmatous atmosphere, generally adapt their vegetable diet, as much as may be in their power, to the circumstances in which they are placed. They endeavour, by adding a large proportion of the stimulant and tonic seeds of plants to their aliments, to counteract the debilitating and septic influence of the air which they breathe, and of other sedative causes of disease to which they are more or less exposed. Hot spices are their chief condiments, and even prophylactics: without the use of these their very aliments would become a source of disease; the various kinds of parasitical animals which prey on man would abound to the most loathsome degree, and they would be continually the subject of dysentery, and the other maladies which imperfect or improper nourishment, and an unwholesome climate, induce. The hot spices are, to individuals so circumstanced, more requisite than salt is to the inhabitants of temperate or cold climates, who live chiefly on animal food.—*J. C.*

happy consequence of the climate. Northern nations, on the contrary, are voracious from instinct and necessity. They swallow enormous quantities of food, and prefer those substances which in digestion produce the most heat. Obliged to struggle incessantly against the action of cold, which tends to benumb the vital powers, to suspend every organic motion, their life is but a continual act of resistance to external influences. Let us not reproach them with their voracity and their avidity for ardent spirits and fermented liquors. Those nations that inhabit the confines of the habitable world, in which man is scarcely able to withstand the severity of the climate, the inhabitants of Kamtschatka, the Samoiedes, live on fish that, in the heaps in which they are piled up, have already undergone a certain degree of putrefactive fermentation. Does not the use of a food so acrid and heating, that in our climate it would inevitably be attended with a febrile action, prove plainly the necessity of balancing, by a vigorous inward excitement, the debilitating influence of powers that are operating from without? The abuse of spirituous liquors is fatal to the European transported to the burning climate of the West Indies; yet the Russian drinks spirituous liquors with a sort of impunity, and lives on to an advanced age, amidst excesses under which an inhabitant of the south of Europe would sink.

This influence of climate affects alike the regimen of man in health and that of man in sickness; and it has been justly observed of medicine, that it ought to vary according to the places in which it is practised. Barley, ptisan, honey, and a few other substances, the greater part obtained from the vegetable kingdom, sufficed to Hippocrates in the treatment of diseases; his therapeutic treatment was, in almost every case, soothing and refreshing. Physicians who practise in a climate such as that of Greece, may imitate this simplicity of the father of physic. Opium, bark, wine, spirits, aromatics, and the most active cordials are, on the other hand, the medicines suited to the inhabitants of the North. The English physicians use, freely and without risk, these medicines, which elsewhere would be attended with the utmost danger.

Simple aqueous drinks promote digestion,* by facilitating the solution of the solids, by serving as a vehicle to their divided parts; and when rendered active by saline or other substances, as spirituous liquors are by alcohol, they are further useful in stimulating the organs and exciting their action.

The least compound drinks are possessed, in different degrees, of this double property of dissolving solid aliments and of stimulating the digestive organs. The purest water is rendered stimulating by the air and by the salts which it contains in different proportions; and to the want of that stimulating quality is to be attributed the difficult digestion of distilled water.

The drinks best suited to the wants of the animal economy are those in which the stimulating principles are blended in due proportions with the water which holds them in solution. But almost all the fluids which we drink contain a certain proportion of nutritious particles. Wine, for example, contains these nutritive particles in greater quantity, as it is the produce of a warmer climate, and as saccharine matter predominates in its composition. Thus, Spanish wines are in themselves nourishing, and are perhaps fitter to satisfy hunger than to allay thirst; while the acidulous Rhenish wines, which are merely thirst-allying, scarcely contain any cordial quality. Between the two extremes are the French wines, which possess, in a

* Simple fluids promote this process only when they are taken in small quantity, and when thirst indicates the propriety of resorting to them. If they are used so largely as to dilute in too great a degree the gastric juice, and to over-distend the stomach, especially during meals, they evidently retard digestion.—*J. C.*

nearly equal degree, the treble advantage of diluting the fluids, of stimulating the organs, and of furnishing to the animal economy materials of nutrition.

IV. *Of hunger and thirst.*—By the words *hunger* and *thirst* are meant two sensations, which warn us of the necessity of repairing the loss which our body is continually undergoing from the action of the vital principle. Their nature, as is well observed by M. Gall, is not better known than that of thought. Let us endeavour to explain the phenomena by which they are attended.

The effects of a protracted abstinence are, a diminution of the weight of the body—a diminution which becomes sensible in the course of twenty-four hours,—a wasting of the body from the loss of fat, discoloration of the fluids, especially the blood, loss of strength, excessive sensibility, sleeplessness, with painful sensations in the epigastric region.*

Death from inanition is most easily brought on in those who are young and robust. Thus, the unfortunate father, whose horrible story has been narrated by Dante, condemned to die of hunger, and shut up with his children in a dark dungeon, died the last, on the eighth day, after having witnessed, in the convulsions of rage and despair, the death of his four sons, unhappy victims of the most execrable vengeance ever recorded in the history of man. Haller has related, in his great work on physiology, several instances of prolonged abstinence: if we are to give credit to these accounts, some of which are deficient in the degree of authenticity required to warrant belief, persons have been known to pass eighteen months, two, three, four, five, six, seven, and even ten years, without taking any nourishment. In the Memoirs of the Edinburgh Society is found the history of a woman who lived on whey only for fifty years. The subjects of these cases are mostly weak, infirm women, living in obscurity and inaction, and in whom life, nearly extinct, just shewed itself in an almost insensible pulse, and an unfrequent and indistinct respiration. It is a fact well worthy of observation, that the muscles and viscera of some of them, when examined after death, shone with a light evidently phosphoric.† Can it be that phosphorus is the result of the lowest degree of animalisation? It may be easily conceived, that living in a manner on their own substance, the fluids in such persons have been frequently subjected to the causes which produce assimilation and animalisation, and have undergone the greatest alteration of which they are capable.

The proximate cause of hunger has by some been conceived to depend on the friction of the nervous papillæ of the empty stomach on each other; by others it has been imputed to the irritation produced on its parietes by the accumulation of the gastric juice. It has been thought to depend on the lassitude attending the permanent contraction of the muscular fibres of the stomach, and on the compression and creasing of the nerves during that permanent constriction; on the dragging down of the diaphragm by the liver and spleen, when the stomach and intestines, being empty, cease to support those viscera,—a dragging which is the greater, as a new mode of circulation takes place in the viscera, which are supplied with blood by the cœliac artery, and while the stomach receives less blood, the spleen and liver increase n weight and size, because their supply is increased.‡

* See Appendix, Note I.

† *Nitidissima viscera sunt animalium fame enectorum, et argentei fibrarum fasciculi.*—Haller, *Elem. Phys.* tom. vi. p. 183.

‡ The most prevalent opinions respecting the proximate causes of hunger are, that it is owing to the action of the gastric juice on the stomach, or that it is a sensation connected with the contracted state of this organ and the corrugation of its internal membrane. It is not unlikely that both causes may contribute to the production of this sensation, in consequence of the impression which they may make on the sentient extremities of these cerebro-spinal

Those who maintain that hunger depends on the friction of the parietes of the stomach against each other, when brought together in an empty state, adduce the example of serpents, whose stomach is purely membranous, and who endure hunger a long time; while fowls, whose powerful and muscular stomach is able to contract strongly on itself, endure it with difficulty. But, to say nothing of the great difference of vitality in the organs of a bird and of a reptile, the stomach which continues closing on itself as it is emptied, may contract to such a degree as scarcely to equal in size a small intestine, without its following, as a necessary consequence, that the parietes which are in contact should exert on each other any friction on which the sensation of hunger may depend. In fact, the presence of food is necessary to determine an action of the parietes of the stomach; and as long as it is empty, there is nothing to call forth such action.

Those who think that hunger is mechanically produced by the weight of the spleen and liver, that keeps pulling down the diaphragm, which the empty stomach no longer bears up, observe, that it may be appeased for a time, by supporting the abdominal viscera by means of a wide girdle; that hunger ceases as soon as the stomach is full, before the food can have yielded to it any materials of nutrition. On this hypothesis, which is purely mechanical, as that which explains hunger by the irritation of the gastric juice, by the lassitude of the contracted muscles, by the compression of the nerves,—how shall we explain the fact, that when the hour of a meal is over, hunger ceases for a time? Ought not hunger, on the contrary, to be considered as a nervous sensation which exists in the stomach, is communicated by sympathy to all the other parts, and, keeping up an active and continuous excitement in the organ in which it is principally seated, determines into it the fluids from all parts? This phenomenon, like all those which depend on nervous influence is governed by the laws of habit, by the influence of sleep, and of the passions of the mind, whose power is so great, that literary men, absorbed in meditation and thought, have been known entirely to forget that they required food. Every thing which awakens the sensibility of the stomach, in a direct or sympathetic manner, increases the appetite and occasions hunger. Thus, bulimia depends sometimes on the irritation of a tape-worm in the organs of digestion. The application of cold to the skin, by increasing from sympathy the action of the stomach, has been known to occasion *fames canina*, of which several instances are related by Plutarch (Life of Brutus). Ardent spirits and highly seasoned food excite the appetite, even when the stomach is over-filled. Whatever, on the contrary, blunts or renders less acute the sensibility of the stomach, renders more endurable or suspends the sensation of hunger. Thus, we are told by travellers, that the Turkish dervises and the Indian faquirs endure long fasts, because they are in the habit of using opium, and lull, in a manner, by this narcotic, the sensibility of the stomach. Tepid and

nerves, which reinforce the vital operations of the stomach. The state of the absorbent vessels, and the irritation which the gastric fluid induces on the extremities of those vessels during an empty state of this viscus, ought also to be taken into consideration in our speculations respecting the origin of this sensation.

The following experiment of Dr. W. Philip, detailed in his excellent work on indigestion, appears to confirm the opinion that the influence of the gastric juice on the stomach is, in some way or other, productive of the sense of hunger.

"A person in good health was prevailed upon to abstain from eating for more than twenty hours, and further to increase the appetite by more exercise than usual. At the end of this time he was very hungry; but, instead of eating, excited vomiting by drinking warm water and irritating the fauces. The water returned mixed only with a ropy fluid, such as the gastric fluid is described to be by Spallanzani, or as I have myself obtained it from the stomach of a crow. After this operation, not only all desire to eat was removed, but a degree of disgust was excited by seeing others eat. He, however, was prevailed upon to take a little milk and bread, which in a very short time ran into the acetous fermentation, indicated by flatulence and acid eructations."—*J. C.*

relaxing drinks impair the appetite ; the use of opiates suspends suddenly the action of the stomach.

V. *Of thirst.*—The blood, deprived of its serosity by insensible perspiration and by internal exhalation, requires incessant dilution, by the admixture of aqueous parts, to lessen its acrimony; and as the serosity is incessantly exhausting itself, the necessity for repairing that loss is ever urgent.* The calls of thirst are still more absolute than those of hunger, and it is much less patiently endured. If it be not satisfied, the blood and the fluids which are formed from it become more and more stimulating, from the concentration of the saline and other substances which they contain. The general irritation gives rise to an acute fever, with heat and parching of the fauces, which inflame, and may even become gangrenous, as happens in some cases of hydrophobia. English sailors, who were becalmed, had exhausted all their stock of fresh water, and were at a distance from land ; not a drop of rain had for a long while cooled the atmosphere : after having borne, for some time, the agonies of thirst, further increased by the use of salt provisions, they resolved to drink their own urine. This fluid, though very disgusting, allayed their thirst ; but at the end of a few days it became so thick and acrid, that they were incapable of swallowing a mouthful of it. Reduced to despair, they expected a speedy death, when they fell in with a ship which restored them to hope and life. Thirst is increased every time that the aqueous secretions are increased ; thus, it becomes distressing to a dropsical patient, in whom the fluids are determined towards the seat of effusion. It is excessive in diabetes, and in proportion to the increased quantity of urine. In fever it is increased from the effect of perspiration, or because in some of these affections, for example in bilious fevers, the blood seems to become more acrid. Hence the advantage of cooling, diluting, and refreshing drinks, administered copiously, with a view to correct the temporary acrimony occasioned by the absence of a great quantity of the serous parts of the blood, and to lessen the over-excitement of a fluid become too stimulating.

The use of aqueous drink is not the most effectual method of allaying thirst. A traveller, exposed to the scorching heat of summer, finds it advantageous to mix spirits with plain water, which alone does not stimulate sufficiently the mucous and salivary glands, whose secretion moistens the inside of the mouth and pharynx, and covers these surfaces with the substance best

* As hunger seems to depend upon a certain condition of, or impression made upon, the nerves distributed to the stomach, so thirst appears to arise from an altered state of the fluids, which state modifies the functions of the vessels, diminishes, or otherwise alters, the condition of the fluids secreted in the mouth and fauces, and which impresses the nerves of sensation, in these situations, in such a manner as to give rise to the phenomenon under consideration.

As the sense of thirst is induced by a state of the circulating fluids which would become hurtful to the system were it to continue for any considerable period, so this sensation is to be regarded in the light of a watchful guardian, which both points out that state, and the only way in which it can be removed.

The superabundance of saline or stimulating substances in the blood is readily indicated by the sensation induced in the mouth and fauces, which are the first parts to evince the deleterious effects of these substances upon the animal economy : hence the state of these organs is an important index to the condition of the circulating fluids, and of the whole system, in a number of diseases.

Those physiologists who refer the operations of the living body to a galvanic process, carried on by the nervous system on the fluids contained in the vascular, especially in the capillaries, assign, as the proximate cause of thirst, a deficiency of oxygen, and an abundance of the inflammable materials amongst those elements which constitute the fluids circulating at the time in which the sensation is induced, (*Oxygenii autem defectum, et phlogisticorum abundantiam sitim adducere.*) This, or a similar opinion, is entertained by Sprengel, Prochaska, Burdach, and Lenhosseck. The arguments which these systematic writers on physiology adduce, as well as the experiments of Dr. Philip, in support of the theory which ascribes the vital phenomena to galvanic processes taking place in the system, deserve to be calmly considered before they are designated to be either visionary or untenable.—*J. C.*

calculated to suspend, at least for a time, the erethism on which thirst appears to depend.

VI. *Of mastication.**—The organs employed in the mastication of the food are the lips, the jaws, and the teeth: with these are furnished the muscles by which they are moved, and those which form the parietes of the mouth. The motions of the lips are extremely varied, and depend on the single or combined action of their muscles, by which the greater part of the face is covered, and which may be enumerated as follows: Elevators of the upper lip (*caninus*, *incisivus*, *levatores communes labiorum et myrtiformes*.) Depressors of the under lip (*triangularis labiorum*, *quadratus genæ*). Abductors (*buccinator*, *zygomaticus major et minor*, *platysma-myoides*). Constrictors (*orbicularis oris*).

VII.—The motions of the upper jaw are so confined, that some have denied that it has any motion: it, nevertheless, rises a little when the lower jaw descends; but it is principally by the depression of the latter that the mouth is opened. The muscles at the back of the neck, and that part of the digastric muscle nearest the mastoid process, produce a slight elevation of the upper jaw, which moves with the whole head, to the bones of which it is firmly united. This connexion of the upper jaw with the bones of the head renders this jaw less movable in man than in the greater number of animals, in which, freed from the enormous weight of the skull, it stretches out in front of that cavity, over the lower jaw. As we follow downwards the scale of animal existence, the motions of the upper jaw are seen to increase the further we descend from the human species; it is equal to that of the lower jaw in the reptiles, and in several fishes; hence the enormous dimensions of the mouth of the crocodile and shark; hence serpents frequently swallow a prey of a bulk greater than their own, and would be suffocated, but for the power they possess of suspending respiration for a long time, and of waiting patiently till the gastric juice dissolves the food as it is swallowed.

In the act of mastication the upper jaw may be considered as an anvil, on which the lower jaw strikes as a movable hammer; and the motions of the under jaw, the pressure it exerts, and its efforts, would soon have disturbed the connexion of the different bones of which the face is formed, if this unsteady edifice, merely formed of bones in juxta-position, or united by sutures, were not supported, and did not transmit to the skull, the double effort which presses on it from below upwards, and pushes it out laterally. Six vertical columns, the ascending apophyses of the superior maxillary bones, the orbitar processes of the malar bones, and the vertical processes of the palate bones, support and transmit the effort which takes place in the first direction, while the zygomatic processes forcibly press the bones of the face against each other, and powerfully resist separation outwardly or laterally. The lower jaw falls by its own weight when its elevators are relaxed; the external pterygoid muscles, and those attached to the os hyoides, complete this motion, the centre of which is not in the articulation of the jaw to the temporal bones, but corresponds to a line that should cross the coronoid processes a little above the angles of the jaw. It is around this axis that, in falling, the lower jaw performs a motion of rotation, by which its condyles are turned forwards, while its angles are carried backwards. In children, the coronoid processes standing off at a smaller distance from the body of the bone, of which they have nearly the same direction, the centre of motion is always in

* The following operations are comprehended under the process of digestion, namely, 1, mastication; 2, insalivation; 3, deglutition; 4, the action of the stomach; 5, the action of the duodenum; 6, the action of the small intestines; 7, the function of the cæcum; 8, the action of the colon; 9, the expulsion of the fæces.—*J. C.*

the glenoid cavities, which the condyles never quit, however much the jaw may be depressed. By this arrangement, nature has guarded against dislocation, which would have been frequent at an early period of life from crying, during which the jaw is depressed beyond measure, or when, not knowing the just proportion between the capacity of the mouth and the size of the bodies they would put into it, children endeavour to introduce those which it cannot receive. The lower jaw forms a double bended lever of the third kind, in which the power represented by the temporal masseter and internal pterygoid muscles lies between the fulcrum and the resistance, at a smaller or greater distance from the chin.

The mode of articulation of the jaw to the temporal bones allows it only a motion upwards and downwards, in which the teeth of both jaws meet like the blades of scissors, and a lateral motion, in which the teeth glide on each other, producing a friction well calculated to grind the food, which in the first part of the act of mastication was torn or divided.

VIII.—In carnivorous animals, the levator muscles of the under jaw, especially the temporals and masseters, are prodigiously large and powerful. In them the coronoid processes, to which the temporal muscles are attached, are very prominent; the condyles are received into a very deep cavity; while in herbivorous animals, on the contrary, they are less strong and bulky, and the pterygoid muscles, by whose action the lateral or grinding motion is performed, are stronger and more marked. The glenoid cavities are also in them wide but shallow, so that they allow the condyles to move freely on their surface. The comparative power of the levator and abductor muscles of the lower jaw may be easily appreciated by viewing the temporal and zygomatic fossæ. Their depth is always in an inverse ratio, and proportioned to the bulk of the muscles which they contain. In carnivorous animals, the zygomatic arch, to which the masseter is attached, is depressed, and seems to have yielded to the effort of the muscle. In the point of view which we have just taken, man holds a middle station between carnivorous animals and those which feed on vegetable substances; nothing, however, determines his nature better than the composition of his dental arches.

IX.—The small white and hard bones which form the dental arches, are not alike in all the animals whose jaws are furnished with them. All have not, as man, three kinds of teeth. The *laniary** teeth are not to be met with in the numerous class of rodentia. Some are without *incisors;* the former appear more fitted to tear fibrous tissues which offer much resistance. In carnivorous animals they are likewise very long, and bent like curved pincers. The grinders are principally employed in grinding substances previously di-

* After the example of several naturalists, I have thought it right to give that name to the canine teeth; in the first place, because their principal use being to lacerate or tear fibrous tissues, it is fit that they should have a name from their manner of acting on the food, as is the case with the incisors and molares; in the second place, because the word *canine* may lead to an erroneous conception, by inducing a belief that this kind of tooth belongs only to one kind of carnivorous animals, while they are stronger and more distinct in the lion, the tiger, &c.

Such an explanation is indispensable, at a period when every body aspires to the easy glory of introducing innovations in language. The invention of words is, however, in the opinion of a celebrated female writer, a decided symptom of barrenness of ideas.

The teeth differ essentially from the other bones; 1st, by the acute sensibility with which they are endowed; 2dly, by the nerves which may be traced into them, while they seem to be wanting in every other part of the osseous system; 3dly, by the mode of distribution of the blood-vessels: these penetrate into them at an aperture which is seen at the extremity of their root, and they expand in the mucous membrane contained in the tooth, and which forms the most essential part of the bone; 4thly, by their not undergoing any change from exposure to the air, a property which they owe to the enamel that covers them externally. It has been said with justice, that nature, in sheathing the tooth with this covering, has imitated the process of tempering, by means of which we harden the edge of steel or iron tools.

vided by the laniary teeth, which tear them, or by the incisors, which, in meeting as the blades of scissors, fairly cut them through; the latter, of which each jaw contains four, acting only on bodies which present but a slight resistance, are placed at the extremity of the maxillary lever. The grinders are brought nearer to the fulcrum, and it is on them that the great stress of mastication rests. If we wish to crush a very hard substance, we instinctively place it between the last large grinders, and by thus shortening considerably the lever between the resistance and the fulcrum, we improve on the lever of the third kind, which, though most employed in the animal economy, acts the most unfavourably. The laniary teeth have very long fangs, which lying deeply buried in the alveolar processes, give them a degree of firmness to enable them to act powerfully, without a danger of being loosened from their situation.

The enamel which covers the teeth preserves the substance of the bone exposed to the contact of the air from the injurious effects which would not fail to result from direct exposure; and as enamel is much harder than bone, it enables the teeth to break the hardest bodies without injury. The concentrated acids soften this substance, and occasion a painful affection of the teeth. The sensibility possessed by these bones is seated in the mucous membrane which lines their inward cavity, through which are distributed the vessels and nerves that enter by openings at their roots. This membrane is the seat of a great number of diseases, to which the teeth are subject. The enamel, incessantly worn by repeated friction, grows and repairs its waste. The alveolar processes which receive the fangs of the teeth firmly embrace them, and all of them being exactly conical in form, every point of these small cavities, and not merely their lower part at which the nerves and vessels enter, supports the pressure which is applied to these bones. When, from accidental causes, or in the progress of age, the teeth are gone, their alveoli first contract, and then disappear; the gums, a reddish and dense membranous substance, which connects the teeth to the sockets, harden and become callous over their thinned edges. Old men, who have lost all their teeth, masticate but imperfectly; and this circumstance is one of the causes of their slow digestion, as the gastric juice acts with difficulty on food whose particles are not sufficiently divided.

X. *Salivary solution.*—The above mechanical trituration is not the only change which the food undergoes in the mouth. Subjected to the action of the organs of mastication, which overcome the force of cohesion of its molecules, it is at the same time imbued with the saliva. This fluid, secreted by the glands placed in the vicinity of the mouth, is poured in considerable quantity into that cavity during mastication.

The saliva is a transparent and viscous fluid, formed of about four parts of water and one of albumen, in which are dissolved phosphates of soda, of lime, and of ammonia, as well as a small quantity of muriate of soda: like all other albuminous fluids, it froths when agitated, by absorbing oxygen, for which it appears to have a strong affinity. Its affinity for oxygen is such, that one may oxydise gold and silver, by triturating in saliva thin leaves of those metals, which are of such difficult oxydisement.

The irritation occasioned by the presence or the desire of food, excites the salivary glands; they swell and become so many *centres of fluxion*, towards which the humours flow abundantly.* Bordeu first called the attention of

* The intimate sympathy or consent of action that exists between the functions of the stomach and the salivary apparatus, by means of the nerves which chiefly preside over the process of digestion and all the operations of secretion and nutrition, is strongly evinced by the following fact. An individual, in an attempt to commit suicide, divided the œsophagus to a con-

physiologists to the great number of nerves and vessels received by the parotid, maxillary, and sublingual glands, from the carotid, maxillary, and lingual arteries, from the portio dura of the seventh pair of nerves, from the lingual nerve of the fifth pair, which penetrate their substance, or pass over a portion of their surface. This great number of vessels and nerves is, proportioned to the quantity of saliva which is secreted, and this is estimated at about six ounces during the average time of a meal. It flows in greater quantity when the food that is used is acrid and stimulating: it mixes with the mucus, copiously secreted with the mucous, buccal, labial, palatine, and lingual glands, and with the serous fluid exhaled by the exhalent arteries of the mouth. The saliva moistens, imbues, and dissolves the ball formed by the aliment, brings together its divided molecules, and produces on them the first change. There can be no doubt that the saliva, mixing with the food by the motion of the jaws, absorbs oxygen, and unites to the alimentary substances a quantity of that gas fit to bring about the changes which they are ultimately destined to undergo.*

XI.—The muscular parietes of the mouth are, during mastication, in perpetual action. The tongue presses on the food, in every direction, and brings it under the teeth; the muscles of the cheek, especially the buccinator, against which the food is pressed, force it back again under the teeth, that it may be

siderable extent. During the endeavours to preserve his existence, food was conveyed into the stomach by means of a tube. As soon as the aliments were received into this viscus, the salivary secretion became abundant, although the process of mastication was not, of course, attempted.—*J. C.*

* The specific gravity of saliva is 1·0038. It mixes with water only by trituration, has a strong affinity for oxygen, absorbs it readily from the air, and gives it out again to other bodies. Whether it possesses any affinity for nitrogen, has not been shewn; nor has the absorption of oxygen by this fluid, during the process of mastication, been sufficiently attended to in our speculations respecting the process of digestion. We can hardly suppose that it takes up oxygen without a portion of nitrogen, or of common air. If any quantity of the latter be mixed with it during the insalivation of the food, an evident source is disclosed from which nitrogen may be conveyed into the circulating fluids, in addition to that portion of it which is derived from the ordinary aliments.

The affinity which the saliva has for oxygen, and the readiness with which it gives out this substance to other bodies, explains the reason why gold or silver triturated with it is oxydised; and why mercury soon disappears when triturated with saliva. Hence, also, the reason why the application of saliva to sores is an useful remedy, and one to which the lower animals have a constant recourse.—*J. C.*

The constituents of saliva, according to Berzelius, are as follow:—

Water	992·9
Peculiar animal matter (precipitated by acet. plumbi), mucus of Bostock	2·9
Mucus†—albumen of Bostock and Thompson	1·4
Alkaline muriates	1·7
Lactate of soda and animal matter	0·9
Pure soda	0·2
	1000·0

† The mucous or albuminous portion has all the characters of albumen. On incineration, its ashes contain a considerable portion of phosphate of lime, although none of that salt can be detected in it before the incineration. It is this peculiar substance which adheres to the teeth, and gives origin to the tartar that surrounds them. This deposition, according to Berzelius, is composed of

Earthy phosphates	79·0
Undecomposed mucus	12·5
Peculiar salivary matter	1·0
Animal matter soluble in mur. acid	7·5
	100·0

It cannot be doubted, that, like the other animal fluids, the constitution of this is liable to changes from disease. It is, however, a subject which has excited little attention among chemists and physiologists. Brugnatelli found the saliva of a patient labouring under an obstinate venereal disease impregnated with oxalic acid.

The concretions which sometimes form in the salivary ducts chiefly consist of phosphate of lime in coagulated albumen.—*J. C.*

duly triturated. When the food has been sufficiently divided, and imbued with saliva, the tip of the tongue is carried to every part of the mouth, and the food is collected on its upper surface. The food having been thus completely gathered together, the tongue presses it against the roof of the mouth, and turning its tip upwards and backwards, at the same time that its base is depressed, there is offered to the food an inclined plane, over which the tongue presses it from before backwards, to make it clear the isthmus of the fauces, and to thrust it into the œsophagus. In this course of the food along the pharynx and into the œsophagus, consists deglutition, a function which is assisted by the co-operation of several organs whose mechanism is rather complicated.

XII. *Deglutition.*—In the process of deglutition, the mouth closes by the approximation of both jaws; at the same time, the submaxillary muscles, the *digastrici*, the *genio-hyoidei*, the *mylo-hyoidei*, &c. elevate the larynx and pharynx, by drawing down the os hyoides towards the lower jaw, which is fixed by its levator muscles. The hyoglossus muscle, at the same time that it elevates the os hyoides, depresses and carries backwards the base of the tongue. Then the epiglottis, situated between these two parts, which are brought together, is pushed downwards and backwards by the base of the tongue, which lays it over the opening of the larynx. The alimentary mass, pressed between the palate and the upper surface of the tongue, slides on the inclined plane formed by the latter, and pressed by its tip, which bends back, clears the isthmus of the fauces. The mucous substance which exudes from the surface of amygdalæ further facilitates the passage of the food. When the food has thus dropped into the pharynx, the larynx, which had risen, and had come forward, and which in that motion had drawn the pharynx along with it, descends and falls backwards. This last organ, stimulated by the presence of the food, contracts, and would in part send it back in a retrograde direction, by the nasal fossæ, if the velum palati, elevated by the action of the levatores palati, stretched transversely by the tensores palati, was not applied to their posterior apertures, and towards the openings of the Eustachian tubes. Sometimes this obstacle is overcome, and the food returns, in part, by the nostrils. This happens, when, during the act of deglutition, we attempt either to laugh or speak. At such times, the air, expelled from the lungs with a certain degree of force, elevates the epiglottis, and meeting the alimentary mass, pushes it back towards the nostrils through which it is to pass. The isthmus faucium is closed against the return of the food into the mouth, by the swelling of the base of the tongue, raised by the action of the constrictor faucium, and of the constrictor pharyngis superior, which are small muscles contained in the thickness of the pillars of the velum.

The alimentary mass is directed towards the œsophagus, and is thrust into that canal by the peristaltic contractions of the pharynx, which may be considered as the narrow part of a funnel-like tube. The solid food passes behind the aperture of the larynx, which is accurately covered over by the epiglottis.* The liquids flow along the sides of that opening, in two channels easily distinguished. They are always of a more difficult deglutition than the solids; the molecules of a fluid have an incessant tendency to separate from one another; and to prevent this separation, the organs are obliged to use greater exertion, and to embrace with more precision the sub-

* During deglutition the glottis is accurately closed, as well as protracted by the epiglottis, so as to prevent the entrance or irritation of foreign substances. Attention to the phenomena of respiration and deglutition, particularly as connected the one with the other, will prove this. The fact, however, has been demonstrated to Magendie and others, who have seen the epiglottis completely destroyed by disease, without either deglutition or speech being impaired.—*J. C.*

stance that is swallowed. Thus, it is observed in those cases in which deglutition is prevented by some organic affection of the œsophagus, that the patients, though they have the power of swallowing solid food, find it difficult to swallow a few drops of a liquid, and are tortured with thirst, though they have still the power of satisfying their hunger.

The deglutition of air and of gaseous substances is still more difficult than that of liquids, because these elastic fluids are much less coercible, and it requires considerable practice to transmit a mouthful of air into the stomach. M. Gosse, of Geneva, had acquired that power from repeated experience, and he made use of it to induce vomiting at pleasure, and by the application of that faculty to the interests of science, he ascertained the digestibility of the articles of food in most common use.

The food descends into the œsophagus, propelled by the contractions of that musculo-membranous duct situated along the vertebral column, from the pharynx to the stomach. Mucus is secreted, in considerable quantity, by the membrane which lines the inner part of the œsophagus, it sheathes the substances which pass along it, and renders their passage more free. The longitudinal folds of the inner membrane allow the œsophagus to dilate; nevertheless, when it is stretched beyond measure, severe pain is experienced, occasioned, no doubt, by the distension of the nervous plexuses, formed by the nerves of the eighth pair, which embrace the œsophagus, as they course along its sides.—I purposely avoid speaking of the weight of the food, as one of the causes which enable it to pass along the œsophagus. Although, in man as in quadrupeds, that weight is no obstacle to deglutition, it favours that function in so slight a degree, that the diminution of muscular contractility at the approach of death is sufficient altogether to prevent it. The act of drinking is then attended with a noise of unfavourable omen. This noise consists in a gurgling of the fluid, which has a tendency to get into the larynx, whose opening is not covered over by the epiglottis; and if it be insisted upon that the patient shall swallow some ptisan, the deglutition of which is impracticable, it flows into the trachea, and the patient dies of suffocation.

XIII. *Of the abdomen.**—Before inquiring any farther into the phenomena of digestion, let us shortly attend to the cavity which contains its principal organs. The abdomen is almost entirely filled by the digestive apparatus, of which the urinary passages form a part; its size, and the structure of its parietes, are evidently adapted to the functions of that apparatus. The capacity of the abdomen exceeds that of the other two great cavities; its dimensions are not invariably fixed, as those of the skull, whose size is determined by the extent of its osseous and inelastic parietes. They are likewise more varying than those of the chest, because the degree of dilatation of which the latter is susceptible, is limited by the extent of motion of which the ribs and sternum are capable. The abdomen, on the contrary, enlarges in a sort of indefinite manner, by the yielding of its soft and extensible parietes.

* It is requisite, in physiology as well as in medical practice, to have an artificial division of the abdominal cavity, in order to point out the exact and relative situations of the viscera which it contains. With this view it has been usually divided into three *regions*, called the *upper*, *middle*, and *under* region: each of these is subdivided into three others. The UPPER region begins at the ensiform cartilage, and extends downwards to about four inches from the umbilicus; the middle of it is termed the *epigastrium*, and the two lateral portions *hypochondria*, from their situation under the cartilages of the false ribs. The MIDDLE region occupies about four inches above and below the umbilicus. Its middle portion is called the *umbilical*, and its lateral parts the *loins* or *lumbar* regions. The UNDER division of the abdominal cavity commences where the former one terminates, or at a line drawn between the superior and anterior spinous processes of the ossa ilii, and forms, in the middle, the *hypogastrium*, or bottom of the belly; and at the sides, the *iliac* regions.—*J. C.*

In some cases of ascites, the abdomen has been known to contain as much as eighty pints of liquid, and yet death has not followed as a consequence of so enormous an accumulation; while by reason of the delicate texture of the brain, of the exact fulness of the skull, and especially of the inflexibility of its parietes, the slightest effusions within that cavity are attended with so much danger; while the collection of a few pints of fluid within the chest occasions suffocation. This vast capacity of the abdomen, capable of being easily increased, was required in a cavity whose viscera, for the most part hollow, and admitting of dilatation, contain substances varying in quantity, and from which are disengaged gases occupying a considerable space. What a difference is there not in the capacity of the abdomen of animals, according to the quality of the food on which they feed! Compare the slender body of the tiger, of the leopard, and of all carnivorous animals, with the heavy mass of the elephant, of the ox, and of all animals that wholly or principally live on vegetable food. In the child, who digests a considerable quantity of food for the purposes of growth and development, the abdomen is much more capacious than in the adult or the old man. In the child, the ensiform cartilage is situated opposite to the body of the eighth or ninth dorsal vertebra. In old men, it descends to the tenth or even the eleventh; so that the capacity of the abdomen decreases with the want of food and with the activity of digestion.

The internal organs of the body are incessantly called into action by different causes and excited to different motions. The action of the arterial system tends to raise the cerebral mass, and to impart to it motions of elevation and depression. The motion of the ribs brings about the expansion and the compression of the pulmonary tissue; the heart, which adheres to the diaphragm, drawn down by that muscle when it descends, strikes against the parietes of the chest every time its ventricles contract. The abdominal viscera are not less agitated by the motions of respiration; they experience from the diaphragm and from the abdominal muscles a perpetual action and re-action, by means of which the circulation of the fluids in their vessels is promoted, the course of the food in the alimentary canal is accelerated, the activity of digestion increased, and several excretions, as of the urine and fæces performed.

XIV. *Of Digestion in the Stomach.**—The food which is taken into the stomach accumulates gradually within its cavity, and separates its parietes, which are always in contact with each other when it is empty. The stomach, in that mechanical distension by the food, yields without re-acting. It is not, however, absolutely passive; its parietes apply themselves by a general contraction, by a kind of tonic motion, to the food which lies within it; and to this action of the whole stomach, the ancients gave the name of *peristole.*† As the stomach dilates, its great curvature is thrust forward, the two folds of the omentum recede from each other, receive it between them, and embrace its outer and dilated part. In man, the principal use of this fold of the peritoneum appears to be to facilitate the dilatation of the stomach, which expands chiefly at its forepart, as may be observed by inflating it in a dead body. As this viscus becomes distended with air, the two folds of the omen-

* See APPENDIX, Note K.

† In order to explain correctly the functions of the stomach, either in their healthy or disordered state, the conformation of the muscular coat requires to be pointed out. This tunic is composed of three strata: the first, or the exterior, consists of longitudinal fibres, proceeding from the œsophagus along the axis of the stomach, and is continued to the duodenum; the *second*, or middle stratum, which is the thickest, is composed of fibres that have an oblique direction, and which, surrounding the stomach, decussate one another; the *third*, or interior stratum, consists entirely of circular fibres, which extend from one curvature of this viscus to the other.—*J. C.*

tum apply themselves to its surface, and if this membrane is pierced with a pin, at the distance of an inch from its great curvature, the pin is observed to get nearer to this curvature ; but the upper portion of the omentum can alone be employed in this use, and the whole of this membranous fold is never entirely occupied by the stomach. Shall we say with Galen, that the omentum guards the intestines against cold, and preserves in them a gentle warmth necessary to digestion ; or, shall we admit the opinion of those who maintain that it answers the purpose of a fluid, filling up spaces, and lessening the effect of friction and pressure from the anterior parietes of the abdomen ; or, shall we assert with others, that the use of the omentum is to allow the blood to flow into it, when the stomach, in a state of contraction, is incapable of receiving it ? May not the blood which flows so slowly in its long and slender vessels, acquire some oleaginous quality which renders it fitter to supply the materials of bile ?*

The stomach likewise stretches, though in a less distinct manner, towards its lesser curvature ; and the laminæ of the gastro-hepatic omentum are separated from each other, as those of the omentum majus. Such is the utility of the gastro-hepatic omentum, which may be considered as a necessary result of the manner in which the peritoneum is disposed in relation to the viscera of the abdomen. This membrane, extending from the stomach to the liver, so as to cover it, could not fill the space which separates those organs, were it not for a kind of membraneous communication that connects them, and in which are contained the vessels and nerves, that, from the lesser curvature, or the posterior edge of the stomach, course towards the concave surface of the liver. The gastro-hepatic epiploon may, besides, by the separation of the two laminæ of which it is formed, favour the dilatation of the hepatic vein, which is situated, as well as the vessels, the nerves, and the excretory ducts of the liver, in the thickness of its right border.

The stomach has ever been considered as the principal organ of digestion, yet its function in that process is but secondary and preparatory : it is not in the stomach that the principal and most essential phenomenon of digestion takes place,—I mean the separation of the nutritive from the excrementitious part of the food. The food when received into the stomach, is prepared for this separation which is soon to be performed, it becomes fluid, and undergoes a material alteration ; it is converted into a soft and homogeneous paste, known under the name of chyme. What is the agent that brings about this change ? or, in other words, in what does digestion in the stomach consist ?

As it is frequently necessary to clear a spot on which one means to build, we will bring forward and refute the hypotheses that have been successively broached to explain the mechanism of digestion. They may be enumerated as follows : *concoction*, *fermentation*, *putrefaction*, *trituration*, and *maceration*, of the food taken into the cavity of the stomach.

XV.—The first of these opinions was that of the ancients and of the father of physic ; but, by the term *concoction*, Hippocrates did not mean a phenomenon similar to that which takes place when food is put into a vessel and exposed to the influence of heat. The temperature of the stomach, which does not exceed that of the rest of the body (32 degrees of Reaumur's

* The omentum seems to lubricate the intestines by means of its adipose halitus, and to aid in facilitating the continual movements of the intestines. It also appears to assist in the reciprocal motion which takes place between the digestive tube and the anterior abdominal parietes, especially in preventing the natural and increased action of the latter, during respiration and muscular exertion, from impeding or injuring the functions of the former. It likewise obviates, during disease, the adhesion of the intestines to the peritoneum covering the abdominal parietes, and the consequent impediment to the operations of the primæ viæ.—*J. C.*

scale), would be insufficient. Cold-blooded animals digest equally with the warm-blooded; and, as Van Helmont observes, febrile heat impairs instead of increasing the powers of digestion. In the language of the ancients, concoction means the alteration, the maturation, the animalisation of alimentary substances, assimilated to our nature by the changes which they undergo in the cavity of the stomach. It is, however, a verified fact, that the natural heat of the stomach promotes and facilitates those changes. The experiments of Spallanzani on artificial digestion shew that the gastric juice is not of more efficacy than plain water in softening and dissolving alimentary substances when the heat is below seven degrees (of Reaumur's scale); that its activity, on the contrary, is greatly increased when the heat is ten, twenty, thirty, or forty degrees above the freezing point. The digestion in the cold-blooded animals is, besides, slower than in the hot-blooded.

XVI.—The abettors of the theory of fermentation admit, that the food taken into the stomach undergoes an inward and spontaneous motion, in virtue of which it forms new combinations, and, as the process of fermentation is promoted by adding to the substance that is undergoing the change a certain quantity of the same which has already undergone the process, some have supposed that there continually exists in the stomach a leaven, formed, according to Van Helmont, by a subtile acid,* and consisting, in the opinion of others, of a small quantity of the food that remains from the former digestion. But, independently of the circumstance that the stomach empties itself completely, and presents no appearance of leaven when examined a few hours after digestion, substances undergoing fermentation require to be kept perfectly at rest, whereas the food is exposed to the oscillatory circulations, and to the peristaltic contractions of the stomach and this viscus is shaken by the pulsations of the neighbouring arteries; it is besides kept in continual motion by the act of respiration. In fermentation gases are either absorbed or extricated, neither of which circumstances takes place when the stomach is not out of order.

It should, however, be stated, in support of the opinion that accounts for digestion on the principle of fermentation, that we can derive nourishment only from substances capable of undergoing fermentation, and that the substances which have undergone the panary and saccharine fermentation are more easily digested and in less time. This imperceptible fermentation, if it really take place, must bear a greater analogy to these two last processes, to those which are called vinous and acetous fermentation, but chiefly to the acid fermentation: indeed, matters received into the stomach soon become somewhat acid, and milk is frequently curdled; but this effect is chiefly remarkable in the stomach of herbivorous animals. The internal membrane of the fourth stomach of a calf preserves for several months its property of curdling milk, and is thus used in the making of cheese. According to Reaumur, the internal membrane of the stomach of the domestic fowl possesses similar virtues. Food insufficiently digested is manifestly acid.† It cannot therefore be doubted that acid properties are developed in substances subjected to the action of the stomach; a circumstance opposed to the notion that digestion is connected with the putrid fermentation.

XVII.—There have been physiologists, however, from the time of Plistonicus, the disciple of Praxagoras, who maintain that digestion is, in fact, the consequence of putrefaction. But not only is ammonia not disengaged

* See APPENDIX, Note K.

† From the experiments of Dr. Prout, published in the Philosophical Transactions for 1824, and of Tiedemann and Gmelin in their work on digestion, the acid found in the stomach during chymifaction is the muriatic, with a little of the acetic. See on this subject the APPENDIX, Notes K.—*J. C.*

during that process, but our digestive organs have the power, as will be seen presently, of retarding, or of suspending, the putrefaction of the substances which are submitted to their action. In serpents, which, in consequence of the great power of dilatation of the œsophagus, and from the power of holding asunder their jaws, both of which are movable nearly in an equal degree, frequently swallow larger animals than themselves, and take several days to digest them,—that part of the animal which is exposed to the action of the stomach is observed to be perfectly fresh, and dissolved to a certain extent, while the part which remains out, exhibits signs of incipient putrefaction. In fine, notwithstanding the heat and moisture of the stomach, the food does not remain in it long enough to allow putrefaction to come on, even though every thing else should favour that process. Animals which have by chance swallowed putrescent animal substances, either reject them by vomiting, or, as Spallanzani has observed in some birds, deprive them of their putridity.

XVIII.—The system of fermentation was invented by the chemists; that of trituration by the mechanical philosophers, who compare the changes which substances undergo in a mortar from the action of the pestle, to the changes which the food undergoes in the stomach. But how different is the triturating action of a pestle, which crushes a substance softer than itself against a resisting surface, to the gentle and peristaltic action of the fibres of the stomach, on the substances which it contains! Trituration, which is a mechanical effect, does not alter the nature of the substance exposed to its action; but the food is decomposed, and no longer the same substance after it has remained some time in the stomach. As this evidently absurd hypothesis has long been held in high estimation, it will not be improper to spend a little time in the refutation of the proofs which are adduced in its support.

The manner in which digestion is brought about in birds whose stomach is muscular, and especially in the gallinaceous fowls, is the most specious argument adduced by the abettors of mechanical digestion. Those granivorous birds all have a double stomach; the first is called the crop, its sides are thin, and almost entirely membranous; a fluid is abundantly effused on its inner surface, the seeds on which they feed get softened, and undergo a kind of preliminary maceration in the crop, after which they are more easily ground by the gizzard, which is a truly muscular stomach, that fulfils the office of organs of mastication, almost entirely deficient in that class of animals. The gizzard acts so powerfully that it crushes the solid substances exposed to its action, reduces into dust balls of glass and crystal, flattens tubes of tin, breaks pieces of metal, and, what is much more extraordinary, breaks, with impunity, the points of the sharpest needles and lancets. Its internal part is lined with a thick semicartilaginous membrane, incrusted with a number of small stones and gravel, taken in with the food of those birds. The turkey cock is, of all other fowls, that in which this structure is most apparent; besides the small pebbles which line its inner membrane, its cavity contains, almost in all cases, a number of them. The rubbing together of these hard substances, exposed along with the seeds among which they are mixed, to the action of the stomach, may assist in breaking them down. The pieces of iron and the pebbles which the ostrich swallows, some of which Valisnieri met with in the stomach of that bird, are destined to the same use. But this mechanical division which the gizzard performs in the absence of organs of mastication, does not constitute digestion; the food, softened and divided by the action of the crop and of the gizzard, passes into the duodenum, and, exposed in that intestine to the action of the biliary juices, undergoes within it the changes most essential to the act of digestion.

The singular structure of the lobster's stomach is not more favourable to

the hypothesis of trituration. In that crustaceous animal the stomach is furnished with a real mandibular apparatus, destined to break down the food. There are found in it, besides, at certain times of the year, two roundish concretions on each side, under its internal membrane. These concretions, improperly termed crabs' eyes, consist of carbonate of lime joined to a small quantity of gelatinous animal matter; they disappear when, after the annual shedding of the shell, the external covering, at first membranous, becomes solid from the deposition of the calcareous matter of which they are formed.

The very great difference between the stomach of these animals and that of man, ought to have precluded every idea of comparing them together. Spallanzani has justly observed, that in regard to the muscular power of the parietes of the stomach, animals might be divided into three classes, the most numerous of which consists of those creatures whose stomach is almost entirely membranous, and furnished with a muscular coat of very little thickness. In this class are contained man, quadrupeds, birds of prey, reptiles, and fishes. Notwithstanding the weakness of that muscular coat, Pitcairn, by a misapplied calculation, has estimated its power at 12,951 pounds; he reckons at 248,335 pounds that of the diaphragm and of the abdominal muscles which act on the stomach and compress it in the alternate motions of respiration. What does so exaggerated a calculation prove, except, as Garat observes, that this vain shew of axioms, definitions, scholia, and corollaries, with which works not belonging to mathematics have been disfigured, have served only to protect vague, confused, and false notions, under the cover of imposing and respected forms? One need only introduce one's hand into the abdomen of a living animal, or a finger into a wound of the stomach, to ascertain that the force of that viscus on its contents does not exceed a few ounces.

XIX.—The learned and indefatigable Haller thought that the food was merely softened and diluted by the gastric juice. This maceration was, in his opinion, promoted and accelerated by the warmth of the part, by the incipient putrefaction, by the gentle but continual motions which the alimentary substance undergoes. Maceration, in time, overcomes the force of cohesion of the most solid substances; but by dilution it never changes their nature. Haller rested on the experiments of Albinus on the conversion of membranous tissues into mucilage by protracted maceration.

In ruminating animals the cavity of the stomach is divided into four parts, which open into one another, and of which the three first communicate with the œsophagus. When the grass, after imperfect trituration by the organs of mastication, whose power is inconsiderable, has reached the paunch, which is the first and largest of the four stomachs, it undergoes a real maceration, together with an incipient acid fermentation. The contractions of the stomach propel, the food, in small quantities at a time, into the bonnet, which is smaller and more muscular than the paunch; it coils on itself, covers with mucus the already softened food, then forms it into a ball, which rises into the mouth by a truly antiperistaltic motion of the œsophagus. The alimentary bolus, after having been chewed over again by the animal, which seems to enjoy that process, descends along the œsophagus into the third stomach, called the manyplus, on account of the large and numerous folds of its inner membrane. From this cavity the food enters into the abomasum, in which the stomachic digestion is completed. Such is the mechanism of rumination, a function peculiar to animals that have four stomachs; they do not, however, ruminate at all periods of their life. The sucking lamb does not ruminate; the half-digested milk does not pass along the paunch or the bonnet, which are useless, but at once descends into the third stomach. Some men

have been capable of a kind of rumination; the alimentary ball, after descending into the stomach, shortly after rose into the mouth, to be there chewed a second time, and to be anew imbued with saliva. Conrad Peyer has made this morbid phenomenon the subject of a dissertation, entitled *Mericologia, sive de Ruminantibus.**

This fourfold division of the stomach, so favourable to Haller's theory, is observed only in ruminating animals. But though animals are in general monogastric, as man, that is, provided with only one stomach, this viscus offers a number of varieties, the most remarkable of which refer to the relative facility which the food meets in remaining within its cavity. The insertion of the œsophagus is nearer to its left extremity, and the great fundus of that viscus is smaller, as animals feed more exclusively on flesh, which is a substance of remarkably easy decomposition, and not requiring for its digestion a long stay in the stomach. In herbivorous quadrupeds, which do not ruminate, this great fundus forms nearly one half, sometimes even the greater part, of the stomach, as the œsophagus enters into it very near the pylorus. In some, as in the hog, the stomach is divided into two parts by a circular contraction. The food which is received into the great fundus of the stomach may remain longer in that viscus, as this part of its cavity lies out of the course of the aliment.

XX. *Of the gastric juices.*—Of all the organs, the stomach probably receives, in proportion to its bulk, the greatest number of blood-vessels; in its membrano-muscular parietes, which are little more than the twelfth part of an inch in thickness, there is distributed the coronary artery of the stomach, entirely destined to that organ, the pyloric and the right gastro-epiploic, given off by the hepatic artery, the *arteriæ breves*, and the left gastro-epiploic, branches of the splenic artery. The greater part of the blood, therefore, which passes from the aorta to the cœliac artery goes to the stomach; for though of the arteries into which that trunk is divided, the coronary of the stomach is the least, the arteries of the liver and spleen send to the stomach several pretty considerable branches before entering the viscera to which they are more particularly allotted. One need only observe the great disproportion between the stomach and the quantity of blood which it receives, to conclude that this fluid is not merely subservient to its nutrition, but is destined to furnish the materials of some secretion.

The secretion in question is that of the gastric juice, which is most abundantly supplied by arterial exhalation from the internal surface of the stomach; it is most active at the instant when the food received within its cavity excites irritation, transforms it into a *centre of fluxion*, towards which the fluids flow from all directions. The state of fulness of the stomach favours the afflux of the fluids into the vessels, as, in consequence of the extension of its parietes, previously collapsed, the vessels are no longer bent and creased. The arteries of the stomach, of the spleen and liver, arising from a common trunk, it may be easily understood how, when the stomach is empty, little blood enters into it in that state of contraction; how, at the same time, the spleen, which is less compressed, and the liver, must receive a larger supply of blood, and again a smaller quantity when the stomach is full.

The gastric juice, the result of arterial exhalation, mixes with the mucus poured out by the mucous follicles of the internal membrane of the stomach. This mixture renders it viscous and ropy, like the saliva, to which, in man, the gastric juice bears a great analogy. It is very difficult to obtain it pure, so as to analyse it; and even if, by long fasting, the stomach should be de-

* See APPENDIX, Notes K.

prived of the alimentary residue which might affect its purity, one could not prevent it being mixed with a certain quantity of liquid bile, which always flows back through the pyloric orifice, turns yellow the inner surface of the stomach in the neighbourhood of that orifice, and even imparts a certain degree of bitterness to the gastric juice. The passage of the bile from the duodenum into the stomach cannot be looked upon as morbid; it occurs in the most perfect health,—which has led to a well-founded opinion, that a small quantity of the biliary fluid is a useful stimulus to the stomach. This opinion is confirmed by an observation of Vesalius, who relates, that he found the ductus communis choledochus opening into the stomach in the body of a convict noted for his voracious appetite. It is further confirmed by what is observed in birds of prey, in the pike, &c., which digest easily and with great rapidity, because the termination into the duodenum of the ductus communis choledochus being very near to the pylorus, the bile easily ascends into the stomach, and is always found there in considerable quantity.

To obtain some of this gastric juice, it is necessary either to open a living animal under the influence of hunger, or to oblige a night bird of prey, as an owl, to swallow small sponges fastened to a long thread. When the sponge has remained for a short time in the stomach, it is withdrawn soaked with gastric juice, of which the secretion has been promoted by its presence in the stomach.

The gastric juice, in its natural state, is neither acid nor alkaline; it does not turn red or green vegetable blue colours. Its most remarkable quality is, its singularly powerful solvent faculty; the hardest bones cannot withstand its action; it acts on those on which the dog feeds; it combines with all their organised and gelatinous parts, reduces them to a calcareous residue, forming those excrementitious substances so absurdly called *album Græcum* by the older chemists. The solvent energy of the gastric juice is in inverse ratio of the muscular strength of the parietes of the stomach; and in those animals in which the parietes of that viscus are very thin and almost entirely membranous, it has most power and activity. In the numerous class of zoophytes it alone suffices to effect decomposition of the food, always more prompt when accompanied by warmth of the atmosphere, as was observed by Du Trembley in the polypi, which in summer dissolve in twelve hours what in colder weather it would take three days to digest. In the actinia, and in the holothuria, the gastric juice destroys even the shells of the muscles which they swallow. Are we not all acquainted with the peculiar flavour of oysters, how much they tend to whet the appetite? This sensation depends less on the salt water contained in the shell than on the gastric juice which acts on the tongue, which softens its tissue, and quickens its sensibility. This mucous substance, when received into the stomach, promotes the digestion of the food which is afterwards taken into it, for the oyster itself is very little nutritious, and is used rather as a condiment than as affording nourishment.

The gastric juice not only pervades and dissolves the food received into the stomach, but it unites and intimately combines with it, completely alters its nature, and changes its composition. The gastric juice acts in a manner peculiar to itself on the food exposed to its action, and, far from inducing a beginning of putrefaction, suspends, on the contrary, and corrects putrescency. This antiseptic quality of the gastric juice suggested the practice of moistening ulcers with it to accelerate their cure; and the experiments made at Geneva and in Italy have, it is said, been fully successful. I have made similar experiments with saliva, which, there is every reason to consider, is very similar to the gastric juice; and I have seen old and foul ulcers assume

a better appearance, the granulations become healthy, and the affection rapidly advance towards a cure, from the use of that irritating fluid. I had under my care an obstinate sore on the inner ankle of the left leg of an adult: notwitstanding the external application of powdered bark, and of compresses soaked in the most detergent fluids, this sore was improving very slowly, when I bethought myself of moistening it every morning with my saliva, the secretion of which was increased by the hideous aspect of the sore. From that time the patient evidently mended, and his wound contracting daily, at last became completely cicatrised,

However powerful the efficacy of the gastric juice to dissolve the alimentary substances, it does not direct against the coats of the stomach its active solvent faculty. These parietes, endowed with life, powerfully resist solution. The lumbrici, so tender and delicate, for the same reason, can exist within it, without being in the least affected by it; and such is this power of vital resistance, that the polypus rejects unhurt its arms, when it happens to swallow them among its food.* But when the stomach and the other organs have lost their vitality, its parietes yield to the solvent power of the juices which it may contain, they become softened, and even in part destroyed, if we may believe Hunter, who found its inner membrane digested in several points in the body of a criminal, who, for some time before his execution, had been prevailed upon, in consideration of a sum of money, to abstain from food.†

* It had been thought that no animal could live on the flesh of its own kind, and this circumstance was explained on the same principle; but to refute it, we need only quote the instance of cannibals and of several tribes of carnivorous animals, who, in the absence of other prey, devour one another.

† The following case of solution of the stomach after death came under the observation of Professor Haviland. The subject was a young man, whose body was opened twelve hours after death; and the stomach, on being examined after its removal from the body, presented the following appearances:—The mucous membrane seemed more red and vascular than usual throughout its whole extent, and here and there were small spots of what seemed to be extravasated blood, lying beneath the mucous coat, as they could not be washed off, nor removed by the edge of the scalpel. There were two holes in the stomach; the larger very near to the cardiac end of the small curvature, and on the posterior surface; this was more than an inch in length, and about half an inch in breadth. The other, not far from the former, and likewise upon the posterior surface, was about the size of a sixpence. The edges of these holes were smooth, well defined, and slightly elevated. The coats of the stomach were thin in many other spots, and in one part nothing was left but the peritoneum, the mucous and muscular coats being entirely destroyed. There was a hole in the diaphragm through the muscular portion, where it is of considerable thickness, large enough to admit the end of the finger. There was no appearance of ulceration or of pus adhering to the edges of this perforation of the diaphragm. Dr. Haviland concludes, that, owing to the activity of the solvent power of the gastric juice, it sometimes not only corrodes the parietes of the stomach, but even the thick muscle of the diaghragm, and that within the space of twelve hours after death, as was exemplified in this case.—*Transactions of the Cambridge Philosophical Society*, vol. i. part ii. 1822.

Hunter's view of this subject has been disputed, to the present day, by several eminent pathologists, and by the author, in a sentence added to the above paragraph in the last edition, from which this edition of the translation is revised; but Dr. Philip's observations are qualified to prove it in a very satisfactory manner to those who yet require convincing arguments. On opening the abdomen of rabbits which had been killed immediately after having eaten, and which were allowed to lie undisturbed for some time before the examination, he has found "the great end of the stomach soft, eaten through, sometimes altogether consumed, the food being only covered by the peritoneum, or lying quite bare for the space of an inch and a half in diameter; and part of the contiguous intestines in the last case also consumed, while the cabbage, which the animal had just taken, lay in the centre of the stomach unchanged, if we except the alteration which had taken place in the external parts of the mass it had formed, in consequence of imbibing gastric fluid from the half-digested food in contact with it."

The following are Dr. Philip's observations:—"We sometimes found the great end of the stomach dissolved within an hour and a half after death. It was more frequently found so when the animal had lain dead for many hours. This effect does not always ensue, however long it has lain dead. It seems only to take place when there happens to be a greater than usual supply of gastric fluid: for we always observed it most apt to happen when the animal had eaten voraciously.

"Why it should take place without the food being digested, is evident from what has been said. Soon after death, the motions of the stomach, which are constantly carrying on towards the pylorus the most digested food, cease. Thus, the food which lies next to the surface of the

The gastric juice is capable, even after death, of dissolving food introduced into the stomach by a wound made into it, provided the animal still preserves some degree of animal heat. It acts on vegetable and animal substances triturated and put into a small vessel, such as those under which Spallanzani, in his experiments on artificial digestion, kept up a moderate heat. Let us not, however, consider as the same this solution of the food in the gastric juice out of the stomach, and that which occurs in digestion within the organ. Every thing tends to shew that the stomach ought not to be considered as a chemical vessel, in which there takes place a mixture giving rise to new combinations. The tying, dividing, or rather removing, a portion of the nerves of the eighth pair,* the use of narcotics and of opium, intense thought, every powerful affection of the mind, trouble, or even gaiety, entirely suspend digestion in the stomach, which cannot take place independently of nervous influence. Yet this nervous influence may possibly not concur directly and of itself to stomachic digestion; it is, perhaps, merely relative to the secretion of the gastric juice, which the ligature or division of the nerves, the action of narcotics, or of other substances, may impede, alter, or even completely suspend.

It is now pretty generally admitted, that digestion in the stomach consists in the solution of the food in the gastric juice.† This powerful solvent penetrates, in every direction, the alimentary mass, removes from one another, or divides its molecules, combines with it, alters its inward composition, and im-

stomach becoming fully saturated with gastric fluid, neutralises no more, and no new food being presented to it, it necessarily acts on the stomach itself, now deprived of life, and, on this account, as Mr. Hunter justly observes, equally subject to its action with other dead animal matter. It is remarkable that the gastric fluid of the rabbit, which in its natural state refuses animal food, should so completely digest its own stomach as not to leave a trace of the parts acted on. I never saw the stomach eaten through, except in the large end; in other parts, its internal membrane is sometimes injured."—*J. C.*

* See the APPENDIX, Note K, for the results of the most recent researches into this subject. —*J. C.*

† Dr. Beaumont published, in the *American Medical Recorder* for January 1828, some interesting experiments made by him upon a young man with a fistulous opening into the stomach. He first introduced into this viscus, through the opening, and attached by means of a silk thread, small pieces of the following substances, the quantity of each being about forty grains: a piece of highly seasoned beef *à la mode*, lean of salted beef raw, lean fresh beef also raw, salted bacon raw, boiled beef, bread, and cauliflower. At the end of two hours the bread, cauliflower, boiled beef, and the bacon, were completely digested, and had separated from the thread: the other substances were scarcely altered; these were returned into the stomach; and, after two hours, the patient complained of pain in the epigastrium, with nausea. They were withdrawn at the end of five hours from the time of their first introduction, scarcely more altered than when removed previously. The liquids of the stomach had an acrid and rancid flavour, and the subject of the experiment complained previous to the removal of the above substances of general debility, nausea, oppression and pain at the stomach, with headach.

Seven days afterwards, the bulb of a thermometer was carefully introduced through the fistulous opening into the stomach, after fasting for a considerable time, and in a few minutes the mercury rose to 100° of F. An ounce of pure gastric juice was withdrawn, by means of a gum elastic tube, and poured into a glass vessel capable of holding three ounces, in which a small piece of salted beef was placed. The vessel was surrounded by water, at the temperature of 100° F., and preserved at that height by means of a sand-bath. At the end of forty minutes the surface of the beef was evidently acted upon. After fifty minutes, solution was becoming very apparent, and after two hours the cellular texture of the beef was completely dissolved, and the muscular fibres separated and floating in the turbid fluid in the form of extremely fine short and white filaments. After five hours, the solution was nearly complete; and at the termination of the ninth hour, the whole was dissolved. The gastric fluid which, when removed from the stomach, was clear and limpid, was now slightly frothy, thickened, and more opaque; and when allowed to stand for a few minutes, deposited a sediment of a flesh colour.

At the same time that the above experiment was being performed with the gastric fluid out of the stomach, a piece of salted beef, of the same weight and form, was introduced through the fistulous opening into the stomach, and, at the end of two hours, it had undergone precisely the same change as that which was placed in the glass vessel, and was completely detached from the thread by which it was held; so that there was an end to further observation respecting it.

The above experiments fully illustrate the accuracy of the opinion stated above.—*J. C.*

parts to it qualities very different from those which it possessed before the mixture. If, in fact, a mouthful of wine or of food is rejected a few minutes after being swallowed, the smell, the flavour, all the sensible and chemical qualities of such substances are so completely altered that they can scarcely be recognised; the vinous substances turned, to a certain degree, sour, are no longer capable of the acetous fermentation. The energy of the solvent power of the gastric juice, perhaps over-rated by some physiologists, is sufficient to dissolve and reduce into a pulp the hardest bones on which some animals feed. It is highly probable that its chemical composition varies at different times; that it is acid, alkaline, or saponaceous, according to the nature of the food. Although the gastric juice be the most powerful agent of digestion, its solvent power requires to be aided by several secondary causes, as warmth, which seems to increase, and, in a manner, to concentrate itself in the epigastric region, as long as the stomach is engaged in digestion; a sort of inward fermentation which cannot be, strictly speaking, compared to the decomposition which substances subject to putrefaction and acescency undergo. The gentle and peristalic action of the muscular fibres of the stomach, which press, in every direction, on the alimentary substance, performs on it a slight trituration, while the moisture of the stomach softens and macerates the food before it is dissolved; one might therefore say, that the process of digestion is at once chemical, mechanical, and vital; in that case, the authors of the theories that have been broached have been wrong, in ascribing to only one cause, such as heat, fermentation, putrefaction, trituration, maceration, and the action of the gastric juice, a process which is the result of a concurrence of these causes united.

The food remains in the stomach during a longer or shorter space of time, according as, by its nature, it yields more or less readily to the changes which it has to undergo. Gosse, of Geneva, ascertained, by experiments performed on himself, that the animal and vegetable fibre, concrete albumen, white and tendinous parts, paste containing fat or butter, substances which have either not undergone fermentation, or which do not readily undergo that process, remain longer in the stomach, offer more resistance to the gastric juice, than the gelatinous parts of animals or vegetables, fermented bread, &c.; that the latter required but an hour for their complete solution, while the former were scarcely dissolved at the end of several hours.

XXI.—The following case throws some light on the mechanism and importance of the action of the stomach in digestion. The patient was a woman, whom I had frequent opportunities of examining at the Hôpital de la Charité, at Paris, in the clinical wards of professor Corvisart, in which she died on the 8th Nivôse, of the year 10, after six months stay in the hospital.

A fistulous opening, of an oval form, an inch and a half in length, and upwards of an inch in breadth, situated at the lower part of the chest, at the upper and left side of the epigastric region, afforded an opportunity of viewing the inner part of the stomach, which, when empty of food, appeared of a vermilion colour, was covered with mucus, its surface wrinkled over with folds, about half an inch deep, and enabled one to distingush the vermicular undulations of these folds, and of all the parts which were in sight. The patient, who was then forty-seven years of age, had this fistula since she was in her thirty-eighth year. Eighteen years before, she had fallen on the threshold of a door, the blow had struck against her epigastric region. The place remained affected with pain, and she became incapable of walking or of sitting otherwise than bent forward, and to the left side. At the end of this long interval, a phlegmonous and oblong tumour appeared on the injured spot: during the nausea and vomiting which supervened, the tumour broke,

and there escaped at the wound left by this rupture, two pints of a fluid which the patient had just swallowed. From that time, the fistula, which at first would scarcely have admitted the tip of the little finger, increased daily; at first it allowed only the fluids to pass, but on the eighth day, the solid food came away freely, and continued to do so till she died. When admitted into the hospital she ate as much as three women of her age, she voided about a pint of urine, and went to stool only once in three days. Her fæces were yellowish, dry, rounded, and weighed more than a pound. Her pulse was very feeble and extremely slow, its pulsation scarcely exceeding forty-five or forty-six beats in a minute. Three or four hours after a meal, an irresistible desire obliged her to take off the lint and compresses with which she covered the fistulous opening, and to give vent to the food which her stomach might happen to contain: it came out rapidly, and there escaped at the same time, and with a noise, a certain quantity of gases. The food thus evacuated exhaled an insipid smell, was neither acid nor alkaline; for the chymous and grayish-coloured pulp into which it was reduced, when suspended in a certain quantity of distilled water, did not affect vegetable blues. The digestion of the food was far from being always complete; sometimes, however, the smell of wine could not be recognised, and the bread formed a viscid, thick, and soft substance, pretty similar to fibrine newly precipitated by the acetous acid, and it floated in a tenacious liquid of the colour of common broth.*

It follows, from the experiments performed at the Ecole de Médecine on these half-digested substances, and on the same before their admission in the stomach, that the changes which they undergo consist in the increase of gelatine, in the formation of a substance which has the appearance of fibrine, without having all its qualities, and in a greater proportion of muriate and phosphate of soda, as well as of phosphate of lime.

This patient was unable to sleep till she had emptied her stomach, which she cleared by swallowing a pint of infusion of chamomile. In the morning there was seen in the empty stomach a small quantity of a ropy frothy fluid, like saliva. It did not turn vegetable blues to a green or red colour, was not homogeneous, but exhibited particles of some degree of consistence, among the more fluid parts, and even albuminous flakes completely opaque. The

* Dr. Prout has made several experiments in order to ascertain the chemical composition of the chyme, from which he obtained the following results:—

No. 1. Chyme of a dog fed on *vegetable* food.—Composed of a semifluid, opaque, yellowish white part, containing another portion of similar colour, but of firmer consistence, mixed with it. Spec. grav. 1·056. It shewed no traces of a free acid, or alkali, but coagulated milk completely when assisted by a gentle heat.

No. 2. Chyme of a dog fed on *animal* food.—This was more thick and viscid than No. 1, and its colour was more inclining to red. Spec. grav. 1·022. It shewed no traces of a free acid, or alkali, nor did it coagulate milk, even when assisted by the most favourable circumstances.

On being subjected to analysis, these two specimens of chyme were found to consist of

	1. Chyme from Vegetable Food.	2. Chyme from Animal Food.
A. Water	86·5	80·
B. Gastric principle, or mucus united with alimentary matters, and apparently constituting the chyme properly so called, mixed with excrementitious matter	6	15·8
C. Albuminous matter, chiefly fibrin		1·3
D. Biliary principle	1·6	1·7
E. Vegetable gluten	5	
F. Saline matters	·7	·7
G. Insoluble residuum	·2	·5
	100·	100·

F. The *saline matters* were obtained by incineration, and consisted chiefly of the muriates, sulphates, and phosphates.—*J. C.*

experiments performed on this fluid shewed that it bore a considerable analogy to saliva, which, however, is rather more liable to putrefaction.

The vermicular motion by which the stomach cleared itself of its contents, took place in two different but not in opposite directions, the one pressing the food towards the fistulous opening, the other towards the pylorus, through which the smaller quantity was allowed to pass.

On opening the body, it was found that the fistula extended from the cartilage of the seventh left rib, as high as the osseous termination of the sixth; its edges were rounded, and from three to four lines in thickness; they were covered with a thin moist skin, of a red colour, and similar to that of the lips. The peritoneal coat of the stomach adhered so firmly to the peritoneum lining the fore part of the abdomen around the opening, that the line of adhesion could not be observed. The opening was in the anterior part of the stomach, at the union of the two-thirds on the left side, with the third on the right of that viscus; that is, about eight fingers' breadth from its greater extremity, and only four from the pylorus. It extended from the greater to the lesser curvature. In other respects it was the only organic affection of that viscus.

It should be stated, that for several years the patient had been thin and emaciated, and had led a languid life, which was terminated by a colliquative diarrhœa. She seemed to be supported only by the small quantity of food which passed through the pylorus into the duodenum, where it received the influence of the bile, whose action on the chyme is, as we shall presently state, absolutely essential to the separation of the nutritious parts. Not that there was any thing to prevent the absorbents of the stomach from taking up a certain quantity of nutritious particles, but that small quantity of food, in an imperfect condition, was of very little service in imparting nourishment; and in that respect she was in similar circumstances to patients who are affected with obstruction of the pylorus, and reject the greater part of their food, when, digestion being over, this contracted opening can no longer allow any food to pass.

XXII.—While the alimentary solution is going on, the two openings of the stomach remain perfectly closed; no gas disengaged from the food escapes along the œsophagus, except when digestion is imperfect. A slight shivering is felt, the pulse becomes quicker and more contracted, the vital power seems to forsake the other organs, to concentrate itself on that which is the seat of the digestive process. The parietes of the stomach are soon called into action; its circular fibres contract in different points; these peristaltic oscillations, at first irregular and uncertain, acquire more regularity, and act from above downwards, and from the left to the right; that is to say, from the cardiac to the pyloric orifice. Besides, its longitudinal fibres shorten it, in the direction of its greatest diameter, and bring nearer to each other its two orifices. In these different motions the stomach rises over the pylorus, so that the angle which it forms with the duodenum almost entirely ceases, and this facilitates the escape of the food. It has been observed, that during sleep digestion takes place much more readily when we lie on the right than on the left side, and this circumstance has been ascribed to the compression of the liver on the stomach. It is much more likely to depend on the circumstance, that when we lie on the right side the passage of the food is facilitated by its own weight, the natural obliquity of the stomach from left to right being increased by the changes attending the presence of the food.

XXIII. *On the uses of the pylorus.*—The pyloric orifice is furnished with a muscular ring, covered over by a fold of the mucous nembrane of the stomach. This kind of sphincter keeps it perfectly closed while digestion is

going on in the stomach, and will not allow a free passage to the food which has not yet undergone a sufficient change. The pylorus, which is endowed with a peculiar and delicate sensibility, may be considered as a vigilant guard, which prevents any thing from passing into the intestinal canal till it has undergone the necessary changes. Several authors, quoted by Haller, have very justly observed, that the alimentary substances do not leave the stomach in the same order that they were received into it, but that they are evacuated according to their degrees of digestibility.

One may say that there really takes place in the stomach a sorting of the different substances which it contains. Those that are most readily dissolved get near to the pylorus, which admits them, rejecting those which, not yet sufficiently digested, cannot produce on it the necessary affection. To this delicacy of *tact*, which I ascribe to the pylorus, will be objected, perhaps, the passage it allows to pieces of money and other foreign indigestible substances. But these bodies, which have always lain some time in the stomach before they make their way into the intestines, repeatedly attempt the orifice of the pylorus, and pass through only when they have at last accustomed it to their contact. The gastric system is under the laws of a secretory gland; and as the roots of the excretory ducts, being endued with a sort of elective sensibility, will not receive the secreted fluid until it has undergone the necessary preparation in the glandular parenchyma, in the same manner the pylorus admits aliments, and gives them passage into the intestines, which may be regarded as the excretory ducts of the stomach only when they have been sufficiently elaborated by the action of this organ.

As the stomach empties itself, the spasm of the skin goes off; the shivering is followed by a gentle warmth; the pulse increases in fulness and frequency; the insensible perspiration is argumented. Digestion brings on, therefore, a general action analogous to a febrile paroxysm; and this fever of digestion, noticed already by the ancients, is particularly observable in women of great sensibility. Nothing positive can be said on the duration of stomachic digestion; food passes sooner or slower from the stomach, according as its nature is such as to resist, more or less, the actions which tend to dissolve it; according, too, to the strength and vigour of the stomach at the time, and to the activity of the gastric juices. Yet we may state from three to four hours as the mean time of their remaining there. It is of consequence to know the time required for digestion in the stomach, that we may not disturb it by baths, bleedings, &c., which would call off towards other organs those powers which ought at that time to be concentrated upon the stomach.

If, as is indisputable, the stomach carries with it, into its action, all the other organs of the economy; if it summons to its aid, so to say, the whole system of the vital powers; if this sort of derivation is the more conspicuous, as the organisation is more delicate, the sensibility more lively, the susceptibility greater,—the importance is apparent of enforcing a strict diet in acute diseases, and in all cases where nature is engaged in an organic operation, which a little increase of irritation could not fail to disorder or to break off. Those who have practised in great hospitals know to how many patients indigestions are fatal. I have seen some with large ulcers, suppuration was copious and healthy, the granulations florid, and all promising a happy issue,—when ignorant friends bring them by stealth indigestible food, with which they cram themselves in spite of the utmost watchfulness. The stomach, used to a mild and moderate regimen, at once overloaded with food, is changed into a *centre of fluxion*, towards which the juices and humours all tend, an irritation is produced beyond that on the ulcerated surface, which in a little time ceases

to secrete pus, the fleshy granulation becomes flabby, extreme oppression is felt; with a difficulty of breathing comes on a pungent pain in the side; the pain, sympathetically felt in the lungs, makes this organ the seat of an inflammatory and purulent congestion, a rattle ensues, and the patients die of suffocation, at the end of two or three days, sometimes in twenty-four hours: and this fatal termination is especially accelerated, when, as I have often witnessed, a blister is applied to the seat of the pain, instead of the ulcerated surface.

It will seem surprising, perhaps, that in the case of which I have just been speaking, it should be in the lungs, and not the stomach itself, that the congestion and the pain take place; but besides that the most permeable organ of the body is the lungs, as well as the weakest and the most easily yielding to *fluctionary motion*,* a host of instances prove what a close sympathy unites it to the stomach. Let us but call to mind pleurisies and bilious peripneumonies, those acute pains of the side which, since Stahl, physicians have so successfully treated with vomits. The rapidity with which their symptoms go off, on the evacuation of the sordes which oppress the stomach, shews clearly that the sympathetic diseases are not owing to the metastasis of bile upon the lungs, and that they do not consist in the simultaneous existence of a gastric affection, and of an inflammatory state of the pleura or of the lungs; but that they are simple gastric affections, in which the lungs are, at the same time, the seat of a sympathetic pain.

The action of the parietes of the stomach ceases only when this viscus is completely cleared of the food it contained. The gastric juice is no longer secreted so freely by the arteries, and the parietes of the viscus, which close upon each other, are chiefly lubricated by the mucus so plentifully secreted by the inner coat.

Digestion in the stomach is essentilly assisted by nervous influence. Many physiologists since Brunner have found that the tying of the eighth pair of nerves (the pneumo-gastriques) provoked vomiting and retarded the work of digestion.† As it is impossible to make this experiment without affecting respiration, a function of very different importance, it becomes difficult to know whether the derangement of digestion did not proceed from the general disturbance brought upon all the functions: however, the brain does appear to be in more immediate sympathy with the stomach than with any other part of the digestive tube. Disgust from the recollection of loathed food excites vomiting. A more than ordinary exertion of the brain relaxes, disorders, and even suspends altogether, the functions of the stomach: an unexpected piece of news, a violent emotion, are attended with a cessation of the strongest sensation of hunger.

It would be useless to bring together in this place proofs of the intimate connexion subsisting between the brain and the stomach, through the intervention of the pneumo-gastric nerves, for the connexion is questioned by no one. The most satisfactory pathological proofs may be adduced in support of it; and the experiments performed by Dr. W. Philip, and confirmed by Girard, Broughton, and Breschet, shew, that the removal of a portion of the pneumo-gastric nerves greatly retards digestion; and that the galvanic current, transmitted through the nerve below the place of its division, restores this function. These experiments seem fully to prove what was indeed al-

* Of all the organs it is that in which we most meet with organic injury; and those who have opened many bodies may have observed how rare it is to find the lungs completely sound in adults and in old men.

† Dr. Haighton has proved, in the most satisfactory manner, that a ligature on the eighth pair of nerves, far from inducing vomiting, renders the stomach incapable of rejecting its contents, even though excited by the most powerful emetics. T.—See *Memoirs of the London Medical Society*, vol. ii. p. 512.

ready evident, namely, that the influence of the eighth pair of nerves upon the digestive process is considerable ; and they further shew, that when this process is impeded by the division of the nerves, the galvanic fluid will, to a certain extent, restore it, and act in an analogous manner to the cerebral influence transmitted to the stomach through the eighth pair of nerves ; but they by no means prove what Dr. Philip seems desirous of establishing,—that the galvanic current and nervous influence are identical in their nature.*

XXIV. *Of vomiting.*—At times, the action of the muscular fibres of the stomach is altogether inverted ; they contract from the pylorus towards the cardia, and this anti-peristaltic motion, in which the contractions are effected more forcibly, more rapidly, and in a manner really convulsive, produces vomiting. Then, the action of the abdominal muscles is added to that of the stomach ; the viscera are driven upwards and backwards, by the contraction of the larger muscles of the abdomen ; the diaphragm rises up towards the chest. If it sunk or were contracted, the œsophagus, which passes in the interval of its two crura, would be compressed, and the passage of the alimentary substances by the cardiac orifice could not take place. Accordingly it is observed, that it is only during expiration that any thing passes from the stomach into the œsophagus. Vomiting may depend upon the obstruction of the pylorus,† on the too irritating impression of any substance on the coats of the stomach, it may be produced by the irritation of some other organ with which the stomach is in sympathy, &c.

The evacuation by the mouth of substances contained in the stomach, depends at once upon the inverted action of this organ, and the pressure exercised upon it by the abdominal parietes. But what share has the stomach in this operation ? Is it the principal agent of the phenomenon ? If we believe Francis Bayle, Chirac, Duverney, Senac, and other physicians, whose opinions have been revived in our days, the stomach is entirely passive in the act of vomiting. According to them, it is only the pressure exercised upon this organ by the diaphragm and abdominal muscles which occasions the operation. On the other hand, Haller and his disciples contend that the stomach performs the essential part of the process, to which the diaphragm and abdominal muscles contribute merely an accessary part. Here, as in many other matters, truth seems to lie between both opinions. The experiments performed by M. Magendie, and which seem to reduce the function of the stomach in this process to a passive state, are in every respect fallacious. The substitution of a bladder for the stomach ; the circumstance of its possessing only one opening, corresponding to that of the cardia, without a second to answer to the pylorus ; and the unnatural and painful conditions in which the subjects of the experiments were placed, fully constitute the *experimentum fallax*, and shew that *experiment* may differ widely from *experience* and correct observation.

Careful examinations of the phenomena of disease are more calculated to throw light upon physiology than painful experiments performed upon the lower animals. Many pathological facts may be adduced in corroboration of the explanation I have given of the phenomenon of vomiting ; and in support of it I may refer to the conclusive observations and reasoning of Professor Lallemand and M. Bourdon on this subject.

It is probable that the action of vomiting may vary in different animals,

* For a fuller discussion on this subject, see the APPENDIX, Note K.

† The best description of the pylorus is given by Blumenbach from Levelling, who designates it an annular fold, "consisting not, like the other rugæ of the stomach, of merely the mucous, but also of fibres derived from the nervous and muscular coats. All these united form a conoidal opening at the termination of the stomach, projecting into the duodenum, as the uterus does into the vagina, and, in a manner, embraced by it."—*J. C.*

conformably to modifications of structure in the organs engaged in the process. It is thus, according to the remark of M. Bertin, that it is extremely difficult for the horse to vomit ; two thick bands of muscular fibres augmenting, in this animal, the strength of the cardiac orifice. Dogs and carnivorous quadrupeds throw up with much facility the contents of their stomachs. Vomiting is still more easy to birds of prey, which, devoid of a diaphragm, in this manner get rid of the injurious parts of animals which they have swallowed. The absence of the diaphragm in these does not at all prevent this process from being readily and fully performed.

In vomiting, then, the expulsion of the contents of the stomach depends both upon the action of the parietes of this organ, and the concurrence of the abdominal muscles. The contents of the viscus, pressed on all sides, escape through the opening which offers the least resistance. The pylorus, surrounded by its ring, resists the passage of the contained matters, which find a readier outlet through the cardia, and thus they pass into the œsophagus, and are expelled by the forcible contractions of its muscular parietes.*

XXV. *Of digestion in the duodenum.*—The food, on quitting the stomach, enters the duodenum, and there experiences new changes, as essential as those which were produced upon it by digestion in the stomach. It might even be said, that as the essence of digestion and its principal object is the separation of the food into two parts, the one recrementitious, and the other chylous or nutritious, the duodenum, in which that separation is performed, is its principal organ. In fact, however carefully one may examine the grayish chyme which is sent out of the stomach, it will be discovered to be a mere slimy homogeneous pulp ; and in more than a hundred animals which I have opened during the process of digestion, I never observed the absorbents of the stomach filled with real chyle, like those of the intestines.

The duodenum may be considered as a second stomach, very distinct from the other small intestines, by its situation exterior to the peritonæum, by its size, and by its readiness of dilatation, the size and regularity of its curvatures, the great number of valvulæ conniventes with which its inner part is furnished, the prodigious quantity of chylous vessels which arise from it, and especially by its receiving within its cavity the biliary and pancreatic fluids. If the situation of the duodenum and the peculiarities of its structure are attended to, it will be readily observed, that every thing in that intestine tends to slacken the course of the alimentary substance, and to prolong its stay within it, that it may remain the longer exposed to the action of these fluids.

The duodenum is, in fact, almost entirely uncovered by the peritonæum, a serous membrane, which, like all those that line the inside of the great cavities, and reflect themselves over the viscera which they contain, by furnishing them external coverings, admits but of little extension, and seems to stretch when these viscera become dilated, only by the unfolding of its numerous duplicatures. Fixed by a rather loose cellular tissue to the posterior side of the abdomen, the duodenum is susceptible of such dilatation as to equal the stomach in size, as is sometimes seen in opening dead bodies. Its

* The above section has been condensed from the last French edition of the work. We conceive that the author is wrong in considering that the muscular contractions of the œsophagus are concerned in the expulsion of the contents of the stomach : we believe that the matters are ejected along the œsophagus by the inverted action of the stomach, and forcible contractions of the abdominal muscles ; that instead of the muscular parietes of the œsophagus being in a state of contraction at the moment, they are either passive or in a state of relaxation ; and that the rising of the diaphragm, and action of the abdominal muscles whilst contributing to the process, occasions, consentaneously with the ejection of the contents of the organ, the expulsion of air from the lungs, which passing through the glottis at the moment of the expulsion of the matters from the stomach, prevents the escape of any part of these matters into the larynx. See APPENDIX, Note L, for further observations on the subject of *vomiting*.—*J. C.*

curvatures depend on the neighbouring organs, and seem almost invariably fixed; lastly, numerous valvulæ line its inner surface, so as to add to the friction, and to increase the extent of surface, and thereby the number of absorbents destined to take up the chyle separated in the duodenum from the excrementitious part of the food, by the action of the fluids poured into it from the united ducts of the liver and pancreas.*

XXVI. *Of the bile, and of the organs which serve for its secretion.*—The bile is a viscous, bitter, and yellowish fluid, containing a great quantity of water, of albumen to which it owes its viscid condition, and oil to which the colouring and bitter principle is united; soda, to which the bile owes the property of turning vegetable blues to a green colour; phosphates, carbonates, and muriates of soda; phosphates of lime and of ammonia; and, lastly, as some say, oxide of iron, and a saccharine substance resembling the sugar of milk. This latter substance, known by the name of *picromel*, is very abundant in the bile of bullocks, and exists but in small quantity in the human bile. The biliary fluid, which the ancients looked upon as animal soap, fitted for effecting a more intimate mixture of the alimentary matter by combining its watery with its fat and oily parts, is, therefore, extremely compound: it is at once watery, albuminous, oily, alkaline, and saline.† The liver, which secretes it,

* The muscular coat of the duodenum is thicker than that of the small intestines. The base of the villi of the mucous tunic is more thickly set with glandular follicles, and the whole duodenum presents a more vascular appearance than any other portion of the intestines.

The experiments of Dr. Prout on chyme, taken from the duodenum, exhibit the following results:—

1. *Vegetable Food.*

Composed of a semifluid, opaque, yellowish white part, having mixed with it another portion of a similar colour, but of firmer consistence. It coagulated milk completely.

Water	86·5
Chyme, &c.	6
Biliary principle	1·6
Vegetable gluten	5
Saline matter	·7
Insoluble residuum	·2
	100

2. *Animal Food.*

More thick and viscid than chyme from vegetable food, and its colour more inclining to red. Did not coagulate milk.

Water	80
Chyme, &c.	15·8
Albuminous matter	1·3
Biliary principle	1·7
Saline matters	·7
Insoluble residuum	·5
	100

† "Human bile differs considerably from that of all other animals. Its colour is sometimes green, sometimes yellowish brown, and sometimes it is nearly colourless. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness, it leaves a brown matter, amounting to 1-11th of the original weight. When this matter is calcined, it yields all the salts which are to be found in the bile. All the acids decompose human bile, and throw down a copious precipitate, consisting of albumen and resin."—THOMSON'S *Chemistry*, &c.

The following is the analysis of human bile according to Berzelius:—

Water	908·4
Picromel	80
Albumen	3
Soda	4·1
Phosphate of lime	·1
Common salt	3·4
Phosphate of soda with some lime	1
	1000.—*J. C.*

is a very bulky viscus, situated in the upper part of the abdomen, and kept in its place chiefly by its attachment to the diaphragm, of which it follows all the motion.

The hepatic artery, which the cæliac sends off to the liver, supplies it only with the blood requisite for its nutrition: the materials of its secretion are brought by the blood of the vena portæ.

This opinion on the uses of the hepatic artery, which I adopt with Haller, cannot rest upon the experiments of those who pretend to have seen the secretion of the bile going on after it was tied. Besides, that the position of this vessel makes the operation almost impossible,—which gives me reason to doubt that ever it was practised,—if we intercept the course of the arterial blood carried to the liver, this viscus, even under the received hypothesis, would remain deprived of nourishment and of action; and the vena portæ would supply it in vain with a blood on which it could exert no influence. When this vein is tied, which is far more easily done than the artery, the secretion of bile is seen to stop; but the experiment which suspends the abdominal venous circulation is too speedily fatal to justify any conclusive inference. It is on analogical proofs that the received hypothesis rests, touching the manner of the biliary secretion. The hepatic artery, remarkably lessened by the branches it has sent off in its way towards the liver, is to that organ what the bronchial arteries are to the lungs; and in the same manner, the branches of the vena portæ, spread through its substance, may be compared to the system of pulmonary vessels. It is still to be confessed, however, that the enormous bulk of the liver, its being found in almost all animals, and the quantity of blood carried into it by the vena portæ, compared to the small secretion there is of bile, lead to the belief, that the blood sent to it from all the other organs of digestion undergoes changes there, on which science possesses as yet no certain data, though the chemists maintain that the liver is, in some sort, the supplementary organ of the lungs, and assists in clearing the blood of its hydrogen and carbon.

This name of *vena portæ* is given to a particular venous system, enclosed in the abdominal cavity, and formed as follows: the veins, which bring back the blood of the spleen and the pancreas, of the stomach and intestinal canal, are united in a very large trunk, which ascends towards the concave face of the liver, and there divides into two branches.* These lie in a deep fissure in the substance of this viscus: they send out, through all its thickness, a multitude of branches, which divide like arterial vessels, and end in part by opening into the biliary ducts or pores, and in part by producing the simple hepatic veins. These veins, situated chiefly towards the convex or upper surface of the liver, bring back into the course of the circulation the blood which has not been employed in the formation of bile, and that which has not served to nourish the substance of the liver; for they arise equally from the extremities of the vena portæ, and from the extremities of the ramifications of the hepatic artery.†

The liver differs from all organs of secretion in this, that the materials of the fluid it elaborates are not supplied to it by its arteries. It should seem that the bile, a fat and oily fluid, in which hydrogen and carbon predominate, could be drawn only from venous blood, in which, as is known, these two principles are in superabundance. The blood acquires the venous qualities

* In two instances, the vena portæ has been found running not to the liver, but directly to the vena cava inferior. One of these is described by Mr. Abernethy, in vol. lxxxiii. of the Philosophical Transactions, and the other by Mr. Lawrence, in vol. iv. of the Medico-Chirurgical Transactions.

† For some observations on the Structure and Functions of the Liver, see APPENDIX, Note M.

as it passes along the course of the circulation, and is supplied with hydrogen and carbon the more fully the slower it flows. Now, it is easy to see that all is naturally disposed for retarding the circulation of the hepatic blood, and to give it eminently the distinguishing properties of venous blood. The arteries which furnish blood to the organs in which the vena portæ rises, are either very flexuous, as the splenic, or frequently anastomose, like the arteries of the intestinal tube, which arteries, of all that are in the body, abound most in visible divisions and anastomoses. It will be seen in the chapter on circulation, how well these dispositions are adapted for retarding the course of the arterial blood. Once carried into the organs of digestion, the blood flows there much more slowly,—whether it be that the coats of the hollow viscera, being collapsed or closed upon themselves, hardly yield it passage, or that the organisation of some one of these viscera is favourable to its stagnation.

The spleen seems to serve this purpose. Does this dingy and soft viscus, lodged in the left hypochondrium, and attached to the great fundus of the stomach, receive the blood into the minute cells of its spungy parenchyma; or does this fluid merely traverse, very slowly, the delicate and tortuous ramifications of the splenic vessels? In other respects, there is no organ that exhibits more variety of number, of bulk, of figure, of colour, and of consistence. Sometimes manifold, often divided into several lobes by deep clefts; its bulk varies, not only in different individuals, but even in the same, at different times of the day, as the stomach, full or empty, admits or rejects the arterial blood, and compresses the spleen between its large extremity and the ribs under which it is situated, or leaves it free.

The blood which fills the tissue of the spleen, blacker, more fluid, richer in oily principles, owes all these qualities,—which led the ancients to consider it as a peculiar substance, called by them the *atra bilis*, or black bile,—to its long-protracted continuance within that viscus.

The branches, which by their union form the vena portæ, have thinner parietes than the other veins of the body, they are not furnished with valves, and they do not readily free themselves of the blood which fills them. The action of these veins is, in fact, so feeble, that it would not suffice to enable them to carry the blood onward, if the gentle and alternate compression of the diaphragm and abdominal muscles on the viscera of the abdomen did not favour its circulation. On reaching the liver, the blood, which is highly venous, is further slackened in its circulation by the increased dimensions of the space in which it is contained, the united calibre of the branches of the hepatic vena portæ exceeding considerably that of the principal trunk. Besides, these vessels are enveloped in the parenchymatous substance of the liver, and can act but feebly. The blood therefore circulates slowly through that organ, and with difficulty returns into the course of circulation. The hepatic veins, which are of pretty considerable calibre, and without valves, remain constantly open; their parietes cannot close and contract on the blood which fills them, on account of their adhesion to the parenchymatous substance of the liver. They open into the vena cava, very near the place at which that vein terminates into the right auricle. The regurgitation of the blood during the contraction of that cavity of the heart, is felt in the veins; and the blood, forced back towards the liver, is exposed for a longer time to its action.

The spleen, therefore, performs only preparatory functions, and may be considered as the auxiliary of the liver, in the secretion of the bile.* It is

* See APPENDIX, Note N, for an account of the latest observations and opinions respecting the Structure and Functions of the Spleen.

observed, that the quantity of the latter increases after the spleen has been extirpated, and that it is less yellow, less bitter, and always imperfect.* The blood which circulates in the omentum is very similar to that of the spleen; I would even say that it contains oily particles, if the drops which I have clearly noticed on its surface might not have come from the adipose tissue of the omentum, which allows the fluid contained in its cells to flow when a small puncture is made into it, in examining the blood contained in its veins.

The bile secreted in the tissue of the liver† is absorbed by the biliary ducts, the union of which forms the hepatic duct. The latter issues from the concave surface of the liver, and conveys the bile either immediately into the duodenum, by means of the ductus communis choledochus, or into the gall-bladder. This small membranous pouch, which adheres by means of cellular tissue to the lower surface of the liver, is in some animals entirely distinct from that organ, and connected with it only by the insertion of its duct into that which comes from the liver. Its inner membrane is soft, fungous, plicated, and always covered with the mucus secreted by the glandular cryptæ which it contains. This mucus defends the gall-bladder against the action of the bile contained in it. The almost parallel course of the hepatic and cystic ducts, the acute angle at which they meet, renders it difficult to account for the passage of the bile into the gall-bladder. This, however, is promoted by the constriction of the common duct, where it passes obliquely between the tunics of the duodenum, forming a narrow valvular opening into this intestine, when it is empty, or in a contracted state. Besides, the neck of the gall-bladder is provided with a spiral valve, which favours the passage of the biliary fluid into this receptacle, as has been well shewn by the experiments performed by M. Amussat before the Academy of Surgery, in March 1824; and it appears, that when the duodenum is empty, the bile regurgitates, in part, from the hepatic duct into the gall-bladder, collects within it, becomes thicker and yellower, and acquires a greater degree of bitterness. Consequently, the use of the gall-bladder is to serve as a reservoir to a portion of the bile, which, by remaining within it, is improved in quality, acquires consistence and bitterness, and is heightened in colour, by the absorption of its fluid parts.

XXVII.—The irritation produced on the parietes of the duodenum, when distended by the chyme, is propagated to the gall-bladder by the cystic and common ducts. The parietes of the gall-bladder then contract, and oblige the bile to flow along the cystic duct into the ductus communis choledochus. The pressure of the distended stomach and intestines on the gall-bladder also favours the excretion of bile. The hepatic bile is, at the same time, more abundantly poured into the duodenum during digestion, from being secreted in greater quantity by the liver, which participates in the irritation affecting the organs of digestion, and secretes a greater quantity. The cystic and hepatic bile, mixed in the ductus communis choledochus, undergoes a change before entering the duodenum, by uniting with the fluid of the pancreas. The excretory duct of the pancreas,—a glandular organ, which, in structure, bears so great an analogy to the parotid glands, that some physiologists, assuming an identity of functions, have called it the abdominal salivary gland,—joins the

* Dr. C. H. Schmidt, in his "Commentatio de Pathologiâ Lienis," (Got. 1816. 4to.), argues, that the vasa brevia contribute to strengthen and nourish the stomach,—that the blood and fluids of dogs deprived of the spleen, is found to tend more rapidly to putrefaction than under ordinary circumstances,—that the spleen performs an analogous office to the liver that the lungs do to the heart,—and that it presides over the preparation and assimilation of the elements of the blood.—*J. C.*

† See, in the chapter on Secretion, the laws which that function obeys.

biliary duct before the latter opens in the duodenum, after having insinuated itself obliquely between the coats of that intestine. It arises within the pancreas, from a great number of radicles which join it, like the feathers of a quill to a common trunk. Its calibre increases in size as it approaches the large end of the pancreas, situated on the right, in the concavity of the second curvature of the duodenum. Nothing precise is known with regard to the nature of the pancreatic fluid ; the striking resemblance of the pancreas to the salivary glands leads to a presumption, that this fluid bears considerable analogy to the saliva. The quantity of fluid secreted by the pancreas is likewise unknown, but it must be considerable, if one may judge from the great number of nerves and vessels which pervade its glandular tissue ; and its quantity is, most probably, increased by the irritation of the food in the duodenum.*

This combination of the united pancreatic and biliary fluids poured on the chyme, penetrates it, renders it fluid, animalises it, separates the chylous from the excrementitious part, and precipitates whatever is not nutritious. In bringing about this separation, the bile itself seems to be divided into two parts ;—its oily, coloured, and bitter portion passes along with the excrements, sheathes them, and imparts to them the stimulating qualities necessary to excite the action of the digestive tube ;—its albuminous and saline particles combine with the chyle, become incorporated with it, are absorbed along with it, and return into the circulation. There may, in fact, be noticed in the alimentary mass, after it has undergone this combination, two very distinct parts—the one is a whitish milky substance, which swims to the surface, and is the least in quantity ; the other is a yellowish pulp, in which, when digestion is healthy, it is not easy to recognise the nature of the food. When the liver is obstructed, and the bile does not flow in sufficient quantity, the fæces are dry and discoloured ; the patients are troubled with obstinate costiveness, the excrement, uncombined with the bitter and colouring matter of the bile, not proving sufficiently irritating to the intestinal canal.

I have just mentioned how the separation of the chyle is performed ; but the mechanism of that separation, and the process of chylification, are absolutely unknown. How does the union of the bile with the chyme operate, in extracting from the latter the recrementitious part, and in making it swim above the rest ? Is there any connexion between that process and the nature of the constituent principles of the bile ? The knowledge of the composition of the bile affords as little assistance in the explanation, as does the knowledge of the chemical properties of the semen in understanding the admirable function of generation. All these acts of the animal economy are as mysterious and inexplicable as the action of the brain in producing thought ; a phenomenon which so many physiologists have considered as exceeding the power of matter, and for which they seem to have reserved all their admiration, though *nil mirari*, which I would translate by *wondering at nothing*, ought to be the motto of any one who has made some progress in the study of the laws of life.

* Opinions are various respecting the quantity of the secreted fluid which the pancreas yields. Autenrieth reckoned the quantity at nine ounces in the twenty-four hours. It has been generally supposed that the quantity of this secretion is considerably augmented at the time that the chyme flows into the duodenum ; and the intimate connexion existing between the ganglial nerves supplying these viscera, favours the conclusion. Magendie, however, rejects this inference, and asserts, without stating the grounds of his opinion, that the flow of the pancreatic juice is least abundant during digestion.

The disordered functions of this organ appear to be very essentially concerned in the production of some diseases which are too often referred entirely to the stomach and small intestines, which, no doubt, become consecutively deranged from this cause ; or, if the actions of the pancreas be not primarily diseased, a co-existent disorder may be present in these allied viscera, and be equally the result of one cause.—*J. C.*

XXVIII. *Of the action of the small intestines.*—After remaining a certain time within the duodenum, the alimentary mass, decomposed by the bile, or rather by the pancreatico-biliary fluid, separated into two parts, the one chylous, the other excrementitious, passes into the jejunum and ileum, which are not easily distinguished from each other, and which differ in their relative length, according to the elements on which anatomists ground the distinction.*

The jejunum and the ileum alone occupy nearly three-fourths of the whole length of the digestive canal; they are straighter than the duodenum, and do not dilate so readily, because the peritonæum, which forms their outer covering, lies over their whole surface, with the exception of the posterior border at which their vessels and nerves enter. It is along that border that they are fixed to the mesentery, a membranous band formed by a duplicature of the peritonæum, which contains the vessels and nerves going to the jejunum and ileum, which prevents knots from forming in the intestines, and is a security against the occurrence of intus-susceptio. It is well known, however, that in some rare cases, intus-susceptio does take place, with utmost danger of the patient's life, who generally dies in the agonies of insufferable colic pains, which nothing can alleviate. The progress of the food along the small intestines is retarded by its numerous curvatures, very aptly compared by some physiologists to the windings of a meandering stream, which fertilises the soil it waters. These numerous convolutions of the intestinal canal favour the long-continued presence of the food within its cavity, so that the chyle expressed from the excrementitious part by the peristalic contractions of the intestine, may present itself to the inhaling mouth of the lacteals, by which it is to be absorbed. These chylous absorbents are in greatest number on the surface of the valvulæ conniventes, which are circular folds of the inner membrane, and these are at a greater distance from each other, the nearer they are to the termination of the ileum. The valvulæ conniventes not only slacken the progress of the food, but by their projections they sink, during the contraction of the bowels, into the alimentary mass, and the lacteals on their surface take up, from its inmost part, the chyle which they are destined to absorb.†

The number of the valvulæ conniventes diminishes with that of the lymphatics. The progress of the alimentary substance is gradually accelerated as it parts with its nutritive and recrementitious particles. A quantity of mucus, secreted by the internal membrane of the small intestines, envelops the chymous mass, and promotes its progress by lubricating it: this intestinal mucus, thrown out by the exhalent arteries,‡ imbues it, renders it liquid, and adds to its bulk. This fluid, which seems to partake of the nature of

* The redness of the parietes of the jejunum, the empty condition of that intestine, its situation in the umbilical region, the great number of its valvulæ conniventes, do not distinguish it from the ileum; for the colour of the intestinal canal varies in different parts of its extent, and the substances which fill it are found in different parts of the canal, according to the progress of digestion at the time the parts are examined, according as the convolutions are situated within the cavity of the pelvis or rise towards the epigastric region, according to the full or empty state of the bladder and stomach; and the number of circular folds, called valvulæ conniventes, diminishes, as one gets near to the termination of the ileum. Winslow surmounted the difficulty, by considering the upper two-fifths of the small intestines as jejunum, and the remaining three-fifths as ileum. This last division, from measurement, is wholly arbitrary, and is besides useless, for there is not, perhaps, above one occasion in which it would be interesting to distinguish the jejunum from the ileum. In operating for hernia, when the intestine is mortified, one would decide the more readily to leave an artificial anus, if one could be sure that the gangrenous portion belonged to the latter intestine; but of this it is absolutely impossible to be certain.

† See Appendix, Note O, for some remarks respecting the mucous coat of the digestive canal, and the functions of the small and large intestines.

‡ This lubricating mucus should be considered as being the secretion of the mucous follicles, rather than a product of the exhalents; whilst the fluid which is poured out by the exhalents may be viewed as serving to dilute the chyme, and facilitate the function of digestion in the intestines.—*J. C.*

albumen and gelatine, and to hold several saline substances in solution, is, for the greater part, recrementitious, and must be very considerable in quantity, if we may judge from the calibre of the mesenteric arteries, and from the extent of the internal surface of the intestines. It is, however, scarcely possible that this exhalation should amount to eight pounds in twenty-four hours, according to Haller's calculation, who, as we shall observe when we treat of the secretions, has generally over-rated their amount.

The peristaltic contractions, by the assistance of which the alimentary mass is sent along the whole course of the small intestines, do not occur in a regular and uninterrupted succession, from the stomach to the cæcum. This undulatory and vermicular motion manifests itself at once, in several points of the length of the tube, whose curvatures straighten themselves at intervals. In this action the intestinal curves are decomposed into a great number of short straight lines, which meet so as to form obtuse angles. The peristaltic motion which affects the muscular fibres of the intestines, is caused by the irritation of the alimentary substance on the sentient parietes of the canal along which it descends towards the great intestines. The jejunum and the ileum, covered by the peritonæum, except at the part which connects them to the mesentery at the time of dilatation, separate the two peritoneal laminæ forming the mesentery. They occupy the space between the branches of the mesenteric vessels, whose last division is always at some distance from the adhering edge of the intestine. If this division of the vessels had taken place nearer to the union of the intestine and mesentery, the intestinal canal would not have admitted of dilatation, without stretching the vessels situated at the angle of separation. It is likewise observed, that in the portions of the digestive tube which are most susceptible of dilatation, the last vascular divisions are most distant. Hence, the left gastro-epiploic artery is always at a greater distance from the great curvature of the stomach than the right; a circumstance of which no anatomist has hitherto taken notice.

XXIX. *Of the functions of the great intestines.*—The alimentary mass, after it has parted with nearly the whole of its nutritive particles, passes from the ileum into the cæcum; it then is received into the great intestines, which are more spacious, though shorter, than the small, forming scarcely a fifth of the whole length of the digestive tube.

A musculo-membranous valvular ring is placed at the oblique insertion of the ileum into the first of the great intestines. This valve, called after Eustachius or Bauhinus, who are considered as its discoverers, though the merit of the discovery belongs to Fallopius, is formed of two semicircular segments, the right edge of which is free, and floats towards the cavity of the cæcum. The more the parietes of that intestine are distended by the substances which it contains, the greater is the difficulty to the retrograde flow of such substances; for, under those circumstances, the two extremities of the valve are placed at a greater distance, and its edges, which are free, close on each other, like those of a button-hole whose angles are drawn in opposite directions; besides, the muscular fibres which enter into its structure render it capable of exerting constriction. It is, therefore, calculated to permit the ready flow of matters from the ileum into the cæcum, and forcibly prevent their return into the small intestines. There are facts which lead to a belief that its resistance is sometimes overcome, and that a clyster, thrown in with violence, would force the valve, and be thrown up by vomiting. The great intestines may be considered as a kind of reservoir, destined to contain, for a certain time, the excrementitious, residue of our solid aliments, so as to save us the disgusting inconvenience of constantly parting with it.

As the peritonæum does not wholly cover the great intestines, they are capable of considerable dilatation, and of extending into the cellular substance which connects them to the posterior part of the abdomen. Their muscular coat, which, in a manner, is the base of the intestinal tube, does not consist throughout of circular and longitudinal fibres. The latter, collected into fasciculi, form three narrow bands, in the intervals of which the parietes of the gut are exceedingly weakened, and consequently capable of greater extension. These longitudinal fibres being, besides, shorter than the intestine, crease it transversely, and form within it a number of cavities and cells, marked outwardly by prominences, separated by depressions. If, in addition to these peculiarities of structure, it be considered that in the cæcum* and a great part of the colon, the contents of the bowels have to ascend against their own weight; that the curvature forming the sigmoid flexure of the colon is very considerable; and that, in short, the rectum, before its outer termination in a narrow aperture, is considerably dilated,—it will be evident, that in the great intestines every thing tends to protract the stay of the excrements.

The appendicula vermiformis of the cæcum is, in man, too small to perform this office; in the herbivorous quadrupeds, in which it is much larger, and sometimes not single, it may serve as a reservoir to the fæcal matter. Its existence merely shews, in man, an analogy to those animals in which it is truly useful; and it concurs in manifesting, that nature, in the formation of particular organs in certain kinds of animals, aims at a mere outline which she fills up in others; to shew, as it were, that there are points of resemblance between all beings whom she has gifted with life and motion.

While in the great intestines, the alimentary substance becomes merely fæcal, by parting with the small quantity of chyle which it may yet contain. The number of the absorbents decreases progressively from the cæcum to the rectum; the small number of these vessels accounts for the difficulty of throwing in nourishment by means of clysters, when there is an obstruction to deglutition. The excrements thicken, harden, and become formed or moulded in the cells of the colon; they are then urged by the peristaltic action into the rectum, in the cavity of which they accumulate, till they excite on its parietes an action which determines their expulsion.

XXX. *Of the evacuation of the fæces.*—When a call to evacuate the fæces is experienced, the rectum contracts, while the diaphragm descending, and the abdominal muscles receding towards the spine,† thrust the viscera of the abdomen towards the cavity of the pelvis, and compress the intestines which are filled with fæcal matter. During these efforts the perinæum perceptibly descends, and the fibres of the levator ani are somewhat elongated. The combined action of the rectum and of the abdominal muscles overcomes the resistance of the sphincters, and the alvine evacuation takes place, and is facilitated by the secretion of the mucous follicles of the rectum: these glands, squeezed by the pressure of the fæces, pour out their contents, and lubricate the circumference of its lower aperture. When the fæces have been voided, the diaphragm rises, the large muscles of the abdomen cease

* See the APPENDIX, Note O, for some remarks on the functions of the *cæcum*.—*J. C.*

† Some physiologists have considered as unnecessary this concurrent action of the diaphragm and abdominal muscles: they ground their opinion on the circumstance that animals whose abdomen has been laid open are capable of voiding their fæces. Astruc, one of the luminaries of Montpelier, denies the action of the abdominal muscles in the efforts which one makes at stool; and, in support of his opinion, he brings forward this geometrical proposition, "that a cord disposed in the form of a circle can, by contracting, shorten itself in an infinitely small degree, and, therefore, not perceptibly." On which Pitcairn humorously enough observes, that Astruc had never practised what he reasons upon,—"*credo Astruccium nunquam cacâsse.*"

to press backwards and downwards upon the viscera of that cavity, the perinæum ascends, and the sphincters close, till a renewal of the same call again brings on the same action.

The call to void the fæces is more frequent in children than in adults, because, at an early period of life, the sensibility of the intestinal canal is greater, the contents of the bowels more fluid, and digestion more active. As we advance in years, sensibility becoming impaired, and contractility experiencing a proportionate loss of power, the secretions being likewise less abundant, the bowels become sluggish, the stools more scanty and indurated. They are likewise less frequent and copious in women than in men,—whether it be that the digestive power extracts from the aliment a greater proportion of nutritious matter, or that the menstrual evacuation being a kind of substitute for the intestinal secretions, less remains to add to the bulk of the excrementitious mass. The evacuation of the fæces may be brought on by throwing liquids into the rectum, which dilute the fæces, detach them from the parietes of the intestines, and exciting on these parietes an irritation to which they are not accustomed, determine their contraction.

The fetor of the excrements depends on their incipient putrefaction in the great intestines.* This decomposition is almost always attended with the extrication of gases, in which sulphuretted hydrogen prevails. This gas, which at times escapes, and which at others impregnates the fæces, is the cause of the black colour which they give to silver exposed to their action. One may recognise in the excrements the colouring matter of vegetables, such as the green colour of spinage, the red of beet-root ; one may likewise find among them the fibrous parts of plants and animals, the indurated bark, and the seeds covered with their husks. The digestive juices have so little action on husks, that seeds which have not been broken down by the organs of mastication, frequently continue capable of vegetation.

During the progress of digestion, the food contained in the stomach and intestines absorbs or extricates different gases. M. Jurine, of Geneva, opened the body of a maniac who had been dead a few hours, and collected the gases which escaped : he observed, that the proportion of oxygen and carbonic acid diminishes from the stomach towards the great intestines, while, on the contrary, there is in these an increased proportion of azote ; that hydrogen is more abundant in the great than in the small intestines ; that it is less in quantity in these than in the stomach.† Do the oxygen and azote form a part of the atmospherical air which is taken in with the food and with the saliva, and which is disengaged by the heat of the intestinal canal ? Or are these gases the result of the decomposition of the food and of the intestinal fluids ? Besides, may not the gas contained in the intestines of a dead body have been formed at the moment of death ? We know that, in several instances, at the moment contractility is forsaking our organs, the intestines become distended by gas, which hastens the approach of death, by impeding the descent of the diaphragm.

Digestion, when healthy, is unaccompanied by the production of gases. In indigestion, there almost always escapes carbonated or sulphuretted hydrogen gas, which produces the offensive smell of the air which escapes at the anus : this smell is different from that of the flatus which are brought upwards ; these contain pure hydrogen or carbonic acid gas. The latter is, likewise, sometimes voided by the rectum, but less frequently than hydrogen combined with carbon, sulphur, or even phosphorus. Is not ammonia itself

* The fetor of the excrements, in their ordinary or healthy state, may be more correctly ascribed to the sensible properties of the secretion proceeding from the follicular glands situate in the cæcum, colon, and rectum.—*J. C.*

† See APPENDIX, Note O.

extricated, and does it not accompany the evacuation of the fæces in certain putrid diarrhœas, as in dysentery combined with low fever? Though the formation of this gas implies a putrefactive motion opposed to the vital principle, may not this decomposition commence in substances lying in the great intestines, when these are become almost inert from the impaired condition of the vital power. This would not be the only instance of a chemical process taking place in the intestinal canal, notwithstanding the counteracting influence of vitality. Thus, on some occasions, grapes eaten in too great quantity ferment and produce carbonic acid gas in such abundance, that this elastic fluid overcomes the resistance of the intestines. This is the kind of distension from flatulence which is cured by drinking plentifully of cold water, which dissolves the gas naturally soluble in that fluid.

XXXI. *Of the secretion and excretion of the urine.*—The fluids absorbed with the chyle, and taken up by the lymphatics of the intestinal tube, dilute the nutritive part extracted from the solid aliment, and serve it as a vehicle. When they have reached the mass of the blood, they increase its quantity, diminish its viscidity, and render it more fluid: going along with it throughout the whole course of the circulation, they supply moisture to all the parts of the body, and become loaded with the molecules detached from them by the vital motion. Then, conveyed to the urinary organs, they become disengaged from the rest of the fluids, carrying along with them a number of products of every kind, which by a longer stay in the animal economy would not fail to occasion a manifest disturbance in the exercise of the functions.

XXXII.—The rapidity with which we void, with the urine, certain diuretics, has induced several physiologists to think that there exists a direct communication between the stomach and bladder: no one, however, has yet succeeded in pointing out those peculiar ducts which might serve to convey the urine from the stomach to the urinary organs, without taking the circuitous course of absorption and of the circulation; and, besides, the learned Haller has proved, by accurate calculations, that the size of the renal arteries, whose calibre amounts to an eighth of that of the aorta, and the quickness with which the blood flows, suffice to account for the shortness of the time in which certain fluids reach the urinary organs.*

A thousand ounces of blood pass through the renal tissue in the space of an hour: supposing that this fluid only contains a tenth of the materials fit

* The experiments of Darwin with the nitrate of potash, and of Brande with the prussiate of potash, have led several in modern times, and amongst these, Sir Everard Home, to support the opinion alluded to above. Magendie made experiments in order to ascertain this matter, and deduced from them the following inferences:—

1. Whenever the prussiate of potash is injected into the veins, or absorbed from the intestinal canal, or from a serous surface, it passes quickly into the bladder, where it may be easily recognised in the urine. 2. Whenever a very considerable quantity of the prussiate is injected, it can be detected in the blood by means of reagents; but when the quantity is small, it is impossible to discover its presence by any of the usual tests. 3. That the same thing takes place if the prussiate be mixed with blood in a vessel. 4. That this salt may be detected in the urine in any proportion; and therefore it is by no means extraordinary, that Darwin and Brande could not find in the blood a substance which they easily perceived in the urine.—*Journ. de Phys.* vol. ii. p. 380.

The existence of absorbent vessels which open into veins along their smaller ramifications, and even towards their terminations, and the frequent anastomoses of the former set of vessels with the latter, all which appears to be satisfactorily shewn (see APPENDIX, Note Q,) sufficiently explain the rapid transit of liquids, or other substances, from the stomach and other parts of the body into the circulating fluid, and their quick, but subsequent, appearance in the secretions.

In consequence of the activity of those secreting organs, whose chief function it is to remove substances from the blood which would become deleterious from accumulating in it, and owing to the stimulus which such substances give these organs when conveyed to them in the course of the circulation, they are eliminated from the blood as fast as they enter it, so that they seldom can be present in sufficient quantity to be readily detected by the usual chemical agents.—*J. C.*

for supplying urine, a hundred ounces, or seven pounds and a quarter, may be given out in this short time; and never, with the most copious and diuretic drinks, does more of it pass in an hour. We shall see, however, in treating of absorption, that it is not absolutely impossible, that by means of the numerous anastomoses of the lymphatics, this set of vessels may carry a liquid directly from the stomach into the bladder. It would be superfluous to mention in this place the varieties observable in the kidneys, in point of number, size, and situation. These two lobular viscera,—composed of the union of from twelve to fifteen glandular bodies, divided in the fœtus, and in some quadrupeds attached to the posterior part of the abdomen, and situate behind the peritonæum,—are surrounded with a cellular covering of different thickness, and are particularly remarkable by the consistence, approaching to that of tallow, of the fat which fills its cells.

If ever the art of man shall penetrate into the mystery of the intimate structure of our organs, it seems probable that the kidneys will furnish the first solution of the problem.* Even coarse injections pass readily from the renal arteries into the ureters, or excretory ducts of the kidneys; a convincing proof of immediate communication among the minute arteries, which, exceedingly tortuous, form, with the minute veins, the cortical or outward substance of the kidneys, and the straight urinary tubes, which, distributed in conical fasciculi in the interior of these organs, constitute what has been called its tubuli and papillæ. The passage of injections from the arteries into the renal veins is as easy; and I have often seen the coarsest liquid flowing at once by the ureters and by the emulgent veins. This free communication between the arteries, the veins, and excretory ducts of the kidneys, gives an idea of the rapidity with which the blood must flow through these organs, whose firm consistence allows a very moderate dilatation to the ves-

* One of the latest and most minute dissections of the kidney has been made by Eysenhardt, of Berlin, (*De Structurâ Renum Observationes Anatomicæ*, Ber. 1818, 4to.) His observations were made on very thin slices of the kidney cut longitudinally, and also in the short diameter; these were wetted with diluted alcohol, and examined in the microscope. "The experiments were originally made to discover the peculiarity, if any, of a diabetic kidney;" but no perceptible difference was found to exist between the diabetic and healthy state of this organ.

"The naked eye discovered small points on these slices, which the microscope represented as oval and sometimes as round granulations, situated at different distances from each other, and varying in size, both in the same kidney and in the kidneys of different sexes. After maceration, these grains could be detached with their adhering vessels, and a void was left. They were composed of knotty vessels, surrounded by an ash-gray substance, and united, not so much by frequent anastomoses, as by numerous meetings with each other. The ash-coloured substance was not granular; it appeared as if traced with a pencil. Injection by the renal artery made these corpuscles wholly red; but still, some deeper and other clearer points could be perceived in them. Dr. E. considered these corpuscles to be the glandules and glomerules of Malpighi and of Schumlansky. He could not trace the veins arising from these glandules; but he refers to an observation of Prochascka, in which a successful injection of the renal vein shewed, under the microscope, a very loose, vascular, little net, surrounding the isolated corpuscles of the cortical substance." Dr. Mappes, of Frankfort on the Maine, says, that he has seen distinctly this structure from injections of the hepatic vein, and therefore he infers that the anatomy of the liver and kidney may be similar in other repects.

From these glandules Eysenhardt says, "that the grayish and transparent uriniferous vessels, which seem to be articulated, arise. These vessels form a net-work, which every where unites the glandules with each other. He therefore thinks Schumlansky was deceived in supposing that each glandule had an excretory duct, which, after making numerous curves, ran straight into the medullary substance.

"Little precise information is given by Eysenhardt respecting the medullary part. The excretory ducts, however, which become straight when they pass out of the cortical substance, pass along in fasciculi of about twenty in each fasciculus.

"In a fætus, the cortical substance was smaller in proportion, and the glandules were of scarcely half the size. Each vascular vessel of the medullary substance was composed of granulations, some of them being voluminous, and others much smaller, and all strongly pressed against each other, so that the vessels could no longer be distinguished from each other, but their passage only marked by striæ. The granules were not produced by putrefaction, although putrefaction gives a globular appearance to these parts."—*J. C.*

sels; and suggests the possibility of a sort of filtration of the urinary fluid, the secretion of which would be only a succession of chemical or mechanical separations of the more aqueous portions of the blood in its passage along very minute ducts, of a progressively decreasing diameter. This was the opinion at least of Ruysch, whose system on the intimate composition of our organs, and on the immediate continuation of the blood-vessels with the excretory ducts, is chiefly founded on the facts of structure, discovered to him by his beautiful injections of the renal arteries.

The kidneys are of duller sensibility and less energetic action than the other glands. The force of life has less to do in their secretion, and their functions may be more readily explained on the principles of chemistry or hydraulics.

XXXIII.—If we attempt, indeed, to apply to the urinary organs the fundamental laws on the mechanism of secretions,* it will be seen that these organs are not under their absolute control. Of all the animal fluids, urine is the one most complex in its elements, and most variable in its qualities. Not only do foreign substances sometimes appear in it, affect, and even change its composition; other fluids may at times mix with it, and disguise it altogether. Thus, credible observes tell us of the appearance in urine of bile, fat, milk, blood, pus, of which many facts may be found collected in Haller's great work on physiology. The kidneys, then, have less sensibility than the other secretory organs: they reason less, if I may venture on the expression, on the sensation produced by the various substances in the blood: their action is also less powerful; it does not so intimately affect the fluid subjected to it. It does not change the heterogeneous qualities of those that are mixed with it, but often allows them to pass in a pure state.†

This multitude of elements in the composition of urine had surely been understood by the ancients, before it was demonstrated by modern chemistry; for they considered it as a sort of extract of animal substance, as a real lixivium, carrying off all that is impure in the economy, and gave it the name of *lotium*, which indicates that destination.

Finally, the secretion of urine is more uniformly carried on; it is continual, or at least does not exhibit so prominently those alterations of action and repose, so apparent in the work of the other secretory organs. When, in a case of retention of urine, we introduce a catheter into the urinary bladder and leave it there, the urine keeps dropping continually, and would wet the patient's bed, if the orifice of the catheter were not kept closed. In the memoirs of the Academy of Sciences for the year 1761, there is related a case of singular conformation of the urinary bladder. This musculo-membranous

* See the chapter on *Secretion*.

† This opinion is very different from that entertained by Dr. Thomson. He conceives that it is not merely the abstraction of a quantity of water and of salts accumulated in the blood which the kidneys perform, but that a chemical change is produced by them, either upon the whole blood, or at least upon some important part of it. In proof of this additional function, he adduces the formation of nephrin and uric acid, as he supposes, in the kidneys. "These two substances," he says, "are formed in the kidneys, and as they are thrown out after being formed, without being applied to any useful purpose, they are certainly not formed in the kidneys for their own sake. Some part of the blood then must be decomposed in the kidney, and a new substance, or substances, must be formed; and the urea and uric acid must be formed at the same time, in consequence of the combined action of the affinities which produce the change on the blood; and being useless, they are thrown out, together with a quantity of water and salts, which, in all probability, were useful in bringing about the changes which take place in the arteries and in the kidneys, but which are no longer of any service after these changes are brought about."—THOM. *Syst. of Chem.* vol. iv. p. 62.

This reasoning rests entirely on the assumption that these substances are actually formed in the kidneys; it is quite as probable that they are produced in other parts of the body, and, with other substances, removed from the blood by the action of these organs. See APPENDIX, Note P, for some experiments and farther observations in support of the latter opinion.—*J. C.*

viscus protruded through an opening at the lower part of the linea alba, and was turned inside out, so as to present externally its mucous membrane. This case afforded an opportunity of observing the continual flow of the urine through the orifices of the ureters, and of ascertaining the different circumstances attending this process, either with regard to the qualities of the fluid, or to the quantity which might be voided in a certain space of time; and in this respect there was a good deal of difference, according to the state of sleep and waking, to the quantity and to the diuretic qualities of the drink.

The urine contained in the ureters is turbid and imperfect; its constituent parts are not thoroughly blended together, as may be observed if made to flow by compressing the kidneys in a dead body. It improves by passing along those ducts, acquires the characteristic qualities of urine, oozes at the surface of the papillæ, and flows into the membranous calices which embrace the rounded terminations of the tubuli uriniferi. The union of the calices forms the pelvis, or the expanded portion of the ureters, or membranous ducts, along which the urine is incessantly flowing into the bladder. The urine flows into the bladder by its own weight, and especially by the action of the parietes of the ureters, which possess a certain degree of contractility. To the above causes may be added the concussions excited by the pulsations of the renal arteries, behind which the pelvis of the kidney is situated, and by the pulsations of the iliac arteries, in front of which the ureter passes before entering the cavity of the pelvis; the alternate compression from the viscera of the abdomen during the motions of respiration; the concussion attending bodily exercise, as riding on horseback, walking, running, &c.; the pressure of the column of urine from the kidneys; and the want of resistance towards the bladder.

XXXIV.—The urine is continually passing in drops into the bladder; it separates its parietes, without, however, exciting in them any perceptible impression, as they are accustomed to its stimulus. The urine cannot accumulate in the musculo-membranous cavity of the bladder,* which is situated exterior to the peritonæum, in the cavity of the pelvis behind the pubes, above which, in the adult, it never rises, except when excessively distended, unless it is prevented from flowing along the urethra, or from returning by the ureters. This retrograde flow is prevented by the oblique insertion of these ducts, which pass for some distance between the muscular and mucous coats of the bladder before opening within it, towards the posterior angles of the trigone vesical,† by openings of smaller dimensions than their cavity. The inner coat of the bladder, raised over these apertures, gives them the appearance of being provided with valves, which fit these orifices the better according as the urine contained in the bladder, by separating its parietes, presses against each other the coats by which they are formed, and between which the ureters pass, along a space of from seven to eight lines.

The urine which flows into the bladder requires a certain degree of force to

* In the numerous tribe of birds, the bladder is wanting. In them the ureters open into the cloaca, a musculo-membranous bag, which supplies the place of the rectum, bladder, and uterus, and which serves as a reservoir to the solid excrements, to the urine, and to the eggs detached from the ovaria. The urine of birds dilutes the fæces, and furnishes the carbonate of lime, which forms the basis of the egg-shell. It has such a tendency to concretion, that I have always observed, in dissecting various fowls of different kinds, an earthy, saline, or crystallised substance, forming white striæ, easily seen in the fluid of the ureters through their skin and transparent coats. Hence one may readily conceive how frequently calculi would form in these animals if their urine accumulated and remained for any length of time stationary in a cavity destined to contain it.

† The French anatomists give the name of *trigone vesical* to that portion of the bladder included between the openings of the ureters and the neck of the bladder, and forming a triangle, whose base is represented by a line drawn from the opening of one ureter to the other, and whose apex is situated at the insertion of the urethra into the neck of the bladder.—*T.*

separate its parietes, on which the weight of the intestines presses. This is effected by no other power than by that which causes the flow of the urine along the ureters, and though inconsiderable, it will appear sufficient if it be considered that the fluids which pass from a narrow channel into a larger cavity, act on every superficial portion of its parietes equal to the area of the channel, with a power equal to that which determines their flow into the latter; so that if the urine descends along the ureters with a degree of force equal to one, and if the inner surface of the bladder is a thousand times more extensive than the area of the ureters, the power will be multiplied a thousand fold.

This purely mathematical proposition is expressed by saying, that the force with which the urine passes along the ureters is to that by which the parietes of the bladder are distended, as the calibre of the ureters is to the superficies of the bladder.

The pressure which the urine, accumulated within the bladder, exerts on the lower part of the ureters, does not prevent the force, which determines its descent along the ureters, from carrying it into the bladder:—for, the column which descends along the ureters being higher than that contained in the bladder, these two organs represent an inverted syphon, the longer branch of which is represented by the ureter.

The following are the causes which enable the bladder to retain the urine: the contraction of its sphincter, a muscular ring surrounding the termination of the urethra into the bladder; the angle formed by that canal after it leaves the bladder; and lastly, the action of the anterior fibres of the levator ani, which surround the neck of that organ, surrounded besides and supported by the prostate gland. These fibres, which are calculated to compress the prostate over the neck of the bladder, and to raise the latter against the pubes, have been called by Morgagni, *pseudo-sphincteres vesicæ.*

The urine, deposited by drops into the bladder, gradually separates its parietes. This musculo-membranous organ rises, and at the same time carries upwards the convolutions of the ileum and the peritonæum, before which it lies, behind the pubes and the recti muscles, with which it is in immediate contact. These relations of the peritonæum to the distended bladder account for the possibility of puncturing it above the pubes, so as to let out an accumulation of urine, without penetrating into the cavity of the peritonæum. The urine remains a certain time in the bladder, according to the capacity of the latter, to the irritability and extensibility of its parietes, and according to the acrid or stimulating qualities of the fluid itself. Thus, in old men, in whom the bladder has but a small degree of irritability and contractility, the urine is voided less frequently; it accumulates in greater quantity, and is, at times, evacuated with difficulty. The use of diuretics, especially of cantharides, renders the urine more stimulating; it excites powerfully the parietes of the bladder, and incessantly stimulates it to contraction. Every cause of irritation seated within the bladder itself, or in its vicinity, renders more frequent the calls to void urine. This is observed in cases of stone in the bladder, of piles, gonorrhœa, &c. The urine, while in the bladder, becomes thicker from the absorption of its more fluid parts, its elements become more intimately blended, sometimes even it appears to undergo a certain degree of decomposition.

XXXV.—When, either by the extension which the urine occasions in the muscular fibres of the bladder, or by the irritation which it excites in the nerves distributed on its inner membrane, we experience in the pelvis a sensation of weight, together with a kind of tenesmus, which, as it extends along the urethra, warns us to void urine; then we bring on a contraction of the bladder,

and joining to its action that of the abdominal muscles and of the diaphragm we expel the urine by a process very similar to that of the excretion of the fæces. (XXIX.) It should be observed, however, that in a healthy state of the parts, this assistance is required only to overcome the equilibrium between the contractions of the bladder and the resistance which the cause of retention opposes to the evacuation of the urine. After the simultaneous contractions of the diaphragm and abdominal muscles, which press down the intestines on the bladder, and determine the first flow of the urine, we cease that effort, and the bladder alone, still supporting the weight of the surrounding viscera, which compress it as it empties itself, completes the evacuation. We repeat the first effort, only in case we wish to accelerate the flow of the urine. In the evacuation of the fæces, on the contrary, the muscular coat of the rectum requires the incessant co-operation of the respiratory powers, as these solid substances are evacuated with more effort than the urine. To prove, beyond a doubt, that the urine is evacuated chiefly by the action of the bladder, one need only observe the violent but useless straining of patients affected with retention of urine from paralysis of the bladder.*

The urine is projected along the urethra with the greater force, as it passes from a spacious cavity into a narrow canal, and it is expelled with a force proportioned to that of the muscular coat of the bladder: we know, that in old men this is so weak, that the jet of urine is not projected more than a few inches beyond the urethra. The urethra is not to be considered as inert in the evacuation of the urine; it closes upon it and accelerates its flow, aided in that action by the bulbo-cavernous muscles, to which several anatomists have given a name taken from their functions (*acceleratores urinæ*).

The action of these muscles expels the last drops of urine which remain within the urethra, when the bladder is completely emptied. The contractile and tonic action of the urethra is so distinctly marked, that its spasmodic contraction may be enumerated among the causes which frequently occasion a difficulty in introducing the catheter. If we attempt to inject fluids along the urethra, the moment we remove the pipe of the syringe, which closes its external orifice, that instant the parietes of the canal contract on the fluid, and expel it with a rapid jet.

The bladder and the canal of the urethra are lined internally with a membrane, whose mucous follicles secrete a viscid humour calculated to protect the parietes of these organs against the action of the urine, and to facilitate the evacuation of that fluid. This membrane, whose surface is more extensive than the cavities which it lines, forms a great number of folds, which disappear when the bladder is distended with urine. This mucus is secreted in an unusual quantity in catarrhal affections of the bladder, and becomes, likewise, more ropy and more albuminous. The mucous secretion of the glands of the urethra is altered in its quality, and becomes more abundant, from the action of the venereal poison, and gives rise to the discharge of gonorrhœa; the orifices of these lacunæ may stop the end of a catheter, so as to add to the difficulty of introducing that instrument.†

* It is scarcely credible that some physiologists should have considered this organ as inert, and absolutely passive in the evacuation of the urine, which, in their opinion, is performed by the immediate pressure of the abdominal muscles and diaphragm on that cavity. Amid this variety of opinions, if you wish to come at the truth you must take a medium. *Iliacos intra muros peccatur, et extra.*

† When this operation is performed in a case of simple paralysis of the bladder, it is better to employ a very large catheter, which may stretch the parietes of the urethra, and prevent their forming into wrinkles, and whose rounded beak may not get engaged in the lacunæ of that canal.

When in a case of retention of urine the bladder rises above the pubes, its *bas fond*, or *fundus*, is carried upwards, and there is a period of excessive distension, at which, like the uterus in an advanced state of pregnancy, it seems to make an effort to rise above the brim of the pel-

The urine cannot be voided at the same time as the fæces, when these, by their hardness, compress the prostatic and the membranous part of the urethra, situated before the lower extremity of the rectum. It is difficult, and often impossible, to void urine during a violent erection, as the parietes of the canal are then closely applied to each other, by the turgescence of the corpus spongiosum and of the corpora cavernosa of the penis. The mode of sensibility of the urethra is besides changed in such a manner, that it is calculated to permit only the emission of the seminal fluid.

When the bladder is completely emptied, it sinks behind the pubes ; the tumour which it formed above these bones while in a state of distension collapses, the abdomen becomes less prominent, respiration more free, and there is a general feeling of lightness. The bladder cannot be completely evacuated, unless the pelvis is gently inclined forward ; its *bas fond*, which is on a lower level than its neck, would, in any other posture, retain a certain quantity of urine.

XXXVI. *Of the physical properties of urine.*—As this fluid varies in quantity in a healthy man, according to the quantity and diuretic qualities of the drink, the state of sleep or waking, the condition of the secretions, and especially of the perspiration, it is very difficult to determine accurately its proportions. Nothing varies more than its quantity, as may be ascertained by comparing the different calculations on that subject of a great number of physiologists. At times the urine is less in quantity than the drink that has been taken in, at others more. It may be affirmed, however, that the quantity of urine voided in twenty-four hours is equal to that of the insensible perspiration in the same time, and it may, therefore, be estimated at between three and four pounds in a healthy adult. Its colour varies from a light lemon yellow to an orange approaching to red. Its smell and flavour are peculiar, and distinguish it from every other animal fluid. Its colour is, in general, darker, its smell and flavour stronger and more pungent, as it is less in quantity, as the circulatory system is more active and powerful, and as the substances of our food are more animalised. We all know how fetid and how scanty is the urine of carnivorous animals ; how offensive to the smell is that of the cat ! The specific gravity of urine is greater than that of distilled water, and varies according to the quantity of saline and other substances which it holds in solution : it is, likewise, slighty viscid, but not ropy, like the serum of the blood, the bile, the saliva, and other albuminous fluids.

XXXVII. *Of the chemical properties of urine.**—The peculiar qualities of urine are always more marked in a powerful and adult male than in children, women, and weakly persons. By chemical analysis, the urine is found to contain eleven substances, dissolved in a considerable quantity of water ; viz. urea, a gelatinous animal matter, muriates and phosphates of soda and ammonia, in separate or in triple salts, phosphate of lime, phosphate of magnesia, phosphorus, uric and benzoic acids. Besides these substances, which are constantly found in human urine, this fluid may contain a great number of others ; and if it be true that the urinary system is to be considered as the emunctory of the whole economy, one would expect to find in it, in certain proportions, and under diffierent circumstances, the whole of the constituent principles which analysis has hitherto discovered in our solids and liquids. Hence, doubtless, the difference in the results obtained by the chemists who have investigated the nature of the urine, by allowing it to run into decomposition, or by applying to it various re-agents.

vis : under such circumstances in women, it is impossible to introduce the catheter, except by increasing the curve of the instrument.

* For some observations on the physical and chemical properties of urine, see APPENDIX, Note P.

As the urine is, of all our fluids, that which has the greatest tendency to putrefaction, it should be examined shortly after being voided ; it is then distinctly acid, but in a very short time, and especially if the heat of the atmosphere promotes and accelerates these changes, it becomes turbid, its component parts separate and form various precipitates. Urea and gelatine, which alone of its constituent principles are capable of fermentation and decomposition, give out ammonia, acetous and carbonic acids ; and from the chemical attraction between these newly formed substances, and from the primitive elements, there are produced new compounds, the knowledge of which is of the department of chemistry.

Of all the constituent parts of urine, the most essential is a substance of the consistence of syrup, deliquescent, susceptible of crystallisation, to which M. Fourcroy has given the name of *urea*. This substance, to which the urine owes its characteristic properties, its peculiar colour, smell, and flavour, which was imperfectly known to several chemists who had sketched some of its features, giving it different names, according to the notions they entertained of its nature, was never well understood till the late investigations of this celebrated professor.* It is a compound in which azote prevails, as is shewn by the immense quantity of carbonate of ammonia which it gives out in distillation ; it may be considered as the most animalised product, having such a tendency to the putrid fermentation, that, even while in the animal economy, it is liable to that decomposition, and might overcome the antiseptic influence of the vital power, if nature did not get rid of it by the evacuation of the urine.

Sufficient attention has not hitherto been paid to the symptoms of urinary fever, an affection occasioned by the protracted retention of the urine within the bladder. I have observed, on several occasions, that no kind of fever is attended with more marked signs of what physicians term putridity. The urinous and ammoniacal smell exhaled from the body of the patients, the yellowish and oily moisture of their skin, the parching thirst with which they are tormented, the dryness and redness of their tongue and throat, their frequent and irritable pulse, combined with a flaccid and doughy feel of the cellular tissue,—every thing indicates that the animal frame is threatened with the most speedy and dangerous decomposition.†

I observed similar appearances in a cat and in a rabbit, in which I tied the ureters. Nothing is easier than to find the ureters, and to perform this experiment. After a crucial incision of the parietes of the abdomen, on the left side, the intestines are pushed aside to the left, so as to apply a ligature on the right ureter ; they are then pushed to the right while the left ureter is tied. Both ureters are seen through the peritonæum, situated behind that membrane, in the lumbar region. When the ligatures have been applied to the ureters about the middle, the divided edges of the abdomen are brought together and united by sutures, and the body of the animal is wrapped round with a cloak soaked in some emollient decoction. At the end of six and thirty hours the animals became exceedingly thirsty and restless, their eyes glistening ; their saliva, which flowed copiously, exhaled a smell evidently urinous : on the third day, the cat was seized with vomiting of a slimy substance, remarkable by its having the same smell. This convulsive agitation was followed by an excessive prostration of strength ; it died on the fifth day ; the intestines were not inflamed, the bladder quite empty, the ureters distended with urine between the ligatures and the kidneys, and as large as the ring finger. The kidneys themselves, gorged with urine, were turged, softened, and as if macerated. All the organs, all the fluids, the blood itself, partook

* See his work, entitled, *Système des Connoissances Chimiques*, 8vo. tom. x. p. 153.

† See APPENDIX, Note P.

of this urinous diathesis; putrefaction came on immediately after death, and at the end of a few days an almost complete decomposition of the body had taken place. In the rabbit the symptoms were less violent and rapid; it did not die till the seventh day; the smell of its whole body, though evidently urinous, was less offensive, and the putrefaction which succeeded was less rapid.

These two experiments confirm, in the first instance, what some authors have said of the absence of urine in the bladder, when the ureters have been tied; an undeniable proof that these are the only channels which convey the urine into the bladder: they likewise concur in affording the most convincing proof that the kidneys are the emunctories by means of which the blood clears itself of that part of it which is animalised in excess: finally, they prove that the retention of this fluid is the more dangerous to the animal economy as the urine is itself more animalised.

Has nature the means of supplying the evacuation of urine by other excretions? might this highly recrementitious fluid be, without danger, evacuated by other emunctories? With a view to answer this interesting question, the kidneys have been extirpated in dogs. The removal of one kidney did not prevent the secretion from being carried on; in every case in which both kidneys are removed at once, the animal died in a few days, and on opening the body, there was uniformly found a considerable quantity of bile in the gall-bladder, in the small intestines, and even in the stomach, as if the urea had endeavoured to make its escape in that direction by combining with the bile. As the experiments of MM. Prevost and Dumas have shewn, the extirpation of the kidneys does not impede the formation of urea, which seems to be the *débris* of the organs, absorbed and carried into the circulation.*

Urea, combined with a certain quantity of oxygen, appears to form an acid peculiar to human urine, and which is the substance of the greater numbers of urinary calculi. It resembles urea in this, that its crystals, exposed to heat, give out carbonate of ammonia; but it differs essentially from it by its ready concrescibility. It, in fact, crystallises every time the urine grows cold, and forms the greatest part of the urinary sediment. This acid, so weak that several chemists have considered it to be a mere oxide, has been called by MM. Fourcroy and Vauquelin, the *uric* acid. Among its distinguishing characters, may be mentioned its being insoluble in cold water; it is so fixed, that several thousand times its own weight of boiling water is required to dissolve it; hence it may be easy to account for its so frequently giving rise to urinary calculi: we may, indeed, wonder, that this complaint is not of more frequent occurrence, since a slight cooling of the urine is sufficient to cause a precipitation and crystallisation of the urine. Thus, every time an extraneous substance drops into the bladder, it becomes the nucleus of a calculus, formed by the uric acid becoming concrete on the surface of this body, which is of a colder temperature. Quadrupeds are less frequently affected with urinary calculi, from the absence of the uric acid in their urine, and because carbonate of lime, of which, in those animals, such concretions are formed, is a salt decomposed with effervescence by the weaker acids; and several such acids are found in the urine.

The uric acid is converted into rosacic acid by a slight alteration in the proportion of its constituent elements, as shewn by M. Vogel.† This new acid, discovered by Wollaston, is only found in urine in a small number of cases. It is this acid which sometimes gives the urine its deep colour in inflammatory diseases.

* See the APPENDIX, Note P, for further remarks on this subject.

† Annales de Chimie, Dec. 1815.

Phosphorus, which may be considered as the result of a high degree of animalisation, enters, in considerable proportions, into human urine. Besides the phosphoric salts which it contains, there is always found a certain quantity of disengaged phosphoric acid, which holds in solution the calcareous phosphate, and gives to the urine its manifest acidity when examined fresh, or shortly after it has been voided. It was from urine that phosphorus was first obtained by those who originally discovered it, and from that fluid it has long been procured for the purposes of commerce. But it is seldom obtained from urine since the discovery of the phosphoric acid in the earth of bones has rendered the manufacture of phosphorus easier and less expensive. In the urine of frugivorous mammiferous animals, phosphoric salts have their place supplied by calcareous carbonate.

Certain substances impregnate the urine with a peculiar odour. It is well known, that if one remain a few minutes in a room newly painted with oil of turpentine, the urine, for some time afterwards, gives out a smell of violets; asparagus gives to the urine a very remarkable fetor.

XXXVIII. *Occasional changes in the urine.*—Besides the accidental varieties observed in the urine, varieties which cannot be determined, since the urine is never uniformly the same in its composition, and does not contain the same ingredients in the same person at different times of the day, according to the quantity and quality of the food and drink, the exercise which has been taken, the affections of the mind which have been experienced, &c.; it constantly varies, according to the time which has elapsed since a meal, the age of the subject, and the diseases under which he may labour.

Physiologists have, for a long while, admitted two and even three different kinds of urine, according to the time at which it is voided: they are distinguished by the names of urine of the drink, urine of the chyle, and urine of the blood. The first is a limpid and nearly colourless fluid, which frequently retains, in a remarkable manner, the qualities of the drink, and is voided shortly after drinking, and has scarcely one of the characters of perfect urine. The urine of the chyle or of digestion, voided two or three hours after a meal, is more formed; still it is not perfect, and does not contain all the component parts of this fluid. Lastly, the urine of the blood, which is voided seven or eight hours after a meal, and in the morning after the night's rest, contains, in an eminent degree, all the qualities of urine; hence it is that which chemists prefer using in their analysis. The imperfect state of the two former kinds of urine would prove, better than the rapidity of their secretion, the disputed existence of a peculiar communication from the stomach and intestines into the bladder.

The urine of children and that of nurses contains very little phosphate of lime and phosphoric acid; it is only after the process of ossification is completed, that these elements abound in the urine. That of old men, on the other hand, contains a considerable quantity of these substances; their osseous system already containing phosphate of lime in excess, and incapable of receiving more, this saline substance would ossify all the tissues, as it sometimes does that of the arteries, the ligaments, the cartilages, and membranes, if the urine did not carry off the greater part.

In the rickets, it is by the urine that the phosphate of lime is carried out of the system, and the absence of that substance is the cause of mollities ossium; on the approach of fits of the gout, the phosphoric ingredients of the urine diminish, and seem to be carried to the joints, to produce in their vicinity arthritic concretions.

The great quantity of saline and crystallisable elements which enter into human urine, accounts for the frequency of the concretions which form in that

fluid. Urinary calculi were long considered as formed of a single substance, which the ancients thought analogous to the earth of the bones, and which Scheele took for uric acid. The late investigations of MM. Fourcroy and Vauquelin have shewn, that the component parts of urine are too numerous and too complex to produce uniformly calculi of one kind; that urinary concretions, most frequently formed from uric acid, contain urate of ammonia, phosphate of lime, phosphate of ammonia and magnesia, oxalate of lime, silex; and that these substances, singly, or in binary and ternary combinations, form the materials of nearly six hundred calculi which they analysed. Notwithstanding the extent of these researches, there is reason to believe, that when carried further by the same chemists, they will be attended with results still more varied. For, as there is no integral molecule in the body which may not be voided with the urine, and be found in the urine, so it is conceivable, that under certain circumstances, which it is impossible to assign or to foresee, every thing in the human body that is capable of concretion might supply the materials of urinary concretions.

This variety of elements in the composition of urinary calculi, the absence of signs by which to ascertain their nature, the sensibility of the parietes of the bladder, which would be irritated by agents capable of dissolving the concretions so frequently formed in its cavity, must render it very difficult, not to say impossible, to discover a lithontriptic which should supersede the necessity of a surgical operation, whose difficulties and danger have been much over-rated.

XXXIX. *Urinary calculi.*—The energy of the urinary system in the inhabitants of temperate climates has been considered as the cause of the frequency of calculous affections in Holland, England, and France, while they are very rare in more southern countries, in which the cutaneous perspiration seems to be substituted, in great measure, to the urinary secretion. There is no part of the world in which cases of stone in the bladder are more frequent than in England, and especially in Holland, in which a cold and damp atmosphere is unfavourable to perspiration, which is, at any rate, but scanty in persons of a leuco-phlegmatic temperament like that of the Dutch. In no other country could a lithotomist (Raw) have operated on more than fifteen hundred patients, it is said, successfully. Diabetes, or an immoderate discharge of urine, a disease which appears to depend on an excessive relaxation of the renal tissue, is of frequent occurrence only in cold and damp countries, as Holland, England, and Scotland; it is more rare in France and Germany, and is unknown in warm climates. This relaxation of the renal tissue in diabetes depends on the exhaustion of the urinary organs called into too frequent action, as is proved by the efficacy of tonics and astringents in the treatment of that complaint.

Cutaneous affections, on the contrary, seem to belong to the inhabitants of southern countries. Lepra originated in Judea; the elephantiasis rubra of Cayenne, the frambœsia of Java, the yaws, elephantiasis, herpetic and psoric eruptions, are more frequent among the inhabitants of southern latitudes than among those who live under the temperate zones. In countries near the equator, the surface of the body, habitually exposed to an ardent atmosphere, is powerfully excited; the skin is irritated, and its secretion increased; perspiration becomes so profuse, that it weakens, in a short time, those who, coming from distant countries, are not accustomed to so intense a heat. The activity of the cutaneous system exceeds that of the urinary system, whose action decreases in proportion. These differences in the energy of the two systems account readily for the difference of their diseases; for it is a law of nature, that the more an organ, or system of organs, is called into

action, the more it is liable to disease, which is but a derangement of its action.

Calculous affections are more frequent in children and old people than in adults. In old age, the proportionate quantity of the urine exceeds that of the perspiration. Phosphoric salts, the base of a great number of urinary calculi, are more abundant in old men, as is proved by the ossification in them of the arteries, of the ligaments, of the cartilages, of the membranes, the solidification and the almost universal induration of the different parts. In children, the activity of the urinary system is proportionate to that of the digestive organs. Destined to throw out the residue of nutrition, which at that period is very active, the organs by which the urine is secreted are likewise endowed with considerable energy. Lastly, it is observed, that the greatest number of calculous patients received into the hospitals of large towns come from low and damp streets near to rivers. Every thing, therefore, tends evidently to establish, that the frequency of urinary calculi depends on an increase of activity in the organs destined to the secretion and excretion of urine.

CHAPTER II.

OF ABSORPTION.

XL. Absorption takes place in every part of the body.—XLI. Circumstances influencing the Function of Absorption.—XLII. The Absorbents have Radicles, or open Mouths.—XLIII. Their numerous Anastomoses, and mode of uniting in Trunks, &c.—XLIV. Their Course through, and Connexion with, Glands.—XLV. Structure and Functions of Lymphatic Vessels and Glands.—XLVI. Pathological Views.—XLVII. Of the Thoracic Duct.—XLVIII. Of the Physical and Chemical Properties of the Lymph and Chyle.

XL.—In the history of the phenomena of life, a statement of the functions of the absorbent system ought immediately to follow that of the functions of the digestive organs. The vessels which take up the chyle separated from the food by the action of the organs of digestion, form a considerable part of the absorbent system, bear a perfect resemblance to the other lymphatics, and differ from them only in their origin. When digestion is not going on, those vessels convey lymph absorbed in the intestinal canal, the inner part of which, even when in a state of emptiness, is always bedewed by an abundant quantity of serous mucus.

There exists in all the parts of the human body, in the interior, as well as on the surface of our organs, vessels whose office it is to absorb, and to carry into the mass of the blood those substances by which our machine is maintained and kept in repair, as well as what comes off in the continual destruction of our parts; for, it must not be forgotten, that the organised and living machine, inwardly acted upon by a double impulse, is perpetually undergoing decay and renovation.

XLI.—Absorption is effected on substances introduced from without; such is the absorption from the skin, and the absorption of the chyle, &c. At other times, absorption takes place in fluids effused by arterial transudation; such is the serosity which moistens the serous membranes, the fat, the marrow of the bones,—and this absorption, almost always, bears a proportion to transudation, so that the serosity, absorbed as fast as it is effused on the surface of the membranes which lie in close contact, never accumulates so

as to separate those membranes, except in cases of dropsy. Finally, there is a kind of absorption which may be termed nutritive or molecular, because it exerts its influence on molecules, which, in the process of nutrition, are separated from the organs, and replaced by others. It is this absorption which brings about the decomposition of organs, and to which John Hunter gave the name of interstitial absorption. By means of it, the thymus gland, so voluminous in the fœtus, disappears entirely in the adult. This absorption seems to be incessantly going on, and to carry on decomposition, with a force that cannot be resisted. It explains, in a satisfactory manner, the spontaneous erosions of the living solids, of which ulceration* is the consequence. M. Dumas has endeavoured to explain in this way the sensation of hunger, which, in the opinion of that physician, is felt when the absorbents exert on the solid coats of the stomach their activity previously employed in taking up liquids. But to give even a degree of probability to that supposition, which is entirely gratuitous, it would be necessary to shew, that the parietes of the stomach have been found destroyed or thinned, in persons who have died of hunger. The parietes of the stomach of such persons have, on the contrary, been found thickened and in a state of contraction. This inward absorption is promoted by inflammation; hence the advantage of applying heat to indolent tumours, and of exciting a slight inflammation in swollen glands, in order to bring about resolution. It is on that account, that in swelling and induration of the testicle, unattended by cancer of the part, the operation for hydrocele by injection may be safely employed.—Of this I had a convincing proof a few years ago: a gardener, born deaf and dumb, had had for some years an hydrocele, which he was in the habit of getting tapped every six months. When I last tapped it, I found the testicle swollen and hard, and three times larger than in its natural state; the patient, however, was free from pain. A considerable quantity of a reddish serous fluid was discharged; at the end of two days, inflammation of the tunica vaginalis came on, the scrotum became enlarged, and was covered with emollient poultices. At the end of twenty days, the testicle was a good deal lessened in size, and adhered to the inside of the tunica vaginalis: the cure was considered radical, and proved such; for, though it is now ten years since the operation was performed, the water has not collected, and the patient continues in the laborious employment of his business.

The process of absorption is very active in children, in women, during sleep, in the morning, when the body is refreshed by the night's rest. Is a state of weakness favourable or unfavourable to that process? It is well known, that there are robust men who have intercourse with women infected with the venereal virus, and who escape the contagion, unless they expose themselves to it when debilitated by excesses. A mind free of fear and anxiety has ever been considered in the Eastern countries a safe-guard against the plague. A dog, *cæteris paribus*, is in much less danger from the bite of a viper, when suddenly bitten, than when he has been some time gazing at the reptile, and is, more or less, terrified by the sight. But in all these cases, does debility favour the introduction of the contagious matter, by increasing the force of absorption; or is it not more probable, that by affecting the nervous system, it renders it more susceptible of deleterious impressions?

XLII. *Absorption from the external surface.*—Absorption is much less active on the external surface of the body than on the surface of its internal cavities, and in the very substance of our organs. Cutaneous absorption, under certain circumstances, has even so little activity, as to have led some physiolo-

* *Nosographie Chirurgicale*, tome i. art. *Ulcères Atoniques*.

gists to doubt its existence. The absorbing orifices of vessels which arise on the surface of the body are covered by the epidermis. This covering, which is insensible, and, as it were, inorganic, forms a sort of separation between the external and internal part of our being, and opposes, or renders more difficult, the absorption of substances in immediate contact with our body: and if it be considered that we are frequently immersed in the midst of gases and other substances, to a certain degree deleterious, it will be understood how essential it was that the absorbing surface of the skin should not be entirely exposed, and that cutaneous absorption should not be easily carried on.

The increased weight of the body after exercise in wet weather, — the abundant secretion of urine after remaining long in the bath,— the manifest enlargement of the glands of the groin after keeping the feet immersed, for a considerable time, in water—an experiment often performed by Mascagni on himself,—the effects of mercurial frictions, &c., shew, however, in an unquestionable manner, that absorption takes place through the skin, with more or less rapidity, according to circumstances. It must be taken into account, that the means which promote cutaneous absorption, operate at least as much by altering the structure of the epidermis, as by increasing the action of the absorbing orifices. In this manner the bath appears to operate, by softening the texture of the epidermis; and frictions, by displacing and raising its scales.

It is by means of frictions that we succeed in introducing into the lymphatic system medicines possessing purgative, febrifuge, sedative, or diuretic qualities, combined with the gastric juice, or diluted in any other liquids; for, as has been shewn by the experiments performed at the Salpêtrière, by MM. Dumeril and Alibert, in the name of the Philomathic Society, the mixture with saliva or gastric juice, of the medicines which are to be administered by friction, is not necessary to ensure their absorption. Extract of opium has soothed pain, bark has checked fits of intermittent fever, rhubarb has procured alvine evacuations, squills have stimulated powerfully the action of the urinary organs; nor has the previous mixture of these substances, reduced into powder with gastric juice, seemed to increase or diminish their efficacy.

Absorption takes place quickly and readily wherever the epidermis is thin, habitually moist, and the skin delicate, so as to leave almost bare of covering the subjacent parts, as on the lips, in the inside of the mouth, on the surface of the glands, &c. The complete removal of the epidermis favours absorption from all parts of the skin which it covered. Hence the least scratch on the fingers of an accoucheur touching women infected with the venereal virus, exposes him to this peculiar infection, which, in such cases, is the more to be dreaded, from the admission of the virus by an unusual course. The inoculation of variolous and vaccine matter, equally furnishes proofs of the obstacle which the epidermis presents to cutaneous absorption, and of the facility with which that function takes place, from surfaces denuded of that covering.

Absorption goes on, likewise, with great activity, from the surfaces of internal parts, but it no where is so considerable as in the intestinal canal, and it would perhaps be the most favourable part for introducing medicinal substances into the animal economy, if, when swallowed, they did not undergo changes, by mixing with the gastric juices; or with the intestinal fluids and fæcal substances, when injected by the rectum. From the evacuation by urine of clysters of warm water, soon after they have been administered, it is to be presumed that the great intestines absorb almost as powerfully as the

rest of the digestive canal. A pint of warm water injected into the abdomen of a large dog or sheep, is often absorbed in less than an hour; and the effusions which take place in those cavities would possibly not require an operation to let them out, if such fluids were not subject to coagulation, and if the absorbing surfaces were not diseased.

Besides absorption from surfaces, there exists, as we have already stated, another which takes place in the living solid, and in the internal substance of the organs. It is by this kind of absorption that the nutritive decomposition is effected; by means of it, the living matter is incessantly renovated. Its vitiated action accounts for the spontaneous formation of ulcers; the disappearing of the thymus, the atrophy of parts in which nutrition is carried on in a sluggish manner, the resolution of certain tumours, and many other phenomena, are dependent on the same cause. I do not think, however, that it is possible to admit the explanation of the sensation of hunger adopted by Professor Dumas, who believes that it depends on the action of the absorbing orifices directed against the organised substance of the stomach, in the absence of aliment on which to act. The sensation of hunger is felt only in the stomach, although its effects extend to all parts of the body; it begins in a circumscribed spot, its seat is limited, yet absorption takes place every where,—so that if the hypothesis in question had any foundation, the sensation of hunger ought to be felt at the heel as well as the pit of the stomach.*

The radicles from which the lymphatics arise have orifices so very minute that they are imperceptible to the naked eye; a tolerably accurate notion may be formed of them, by comparing them to the puncta lachrymalia, which are larger and more easily discovered. Each orifice, endowed with sensibility, and with a peculiar power of contraction, dilates or contracts, absorbs or rejects, according as it is affected by the substances which are applied to it. The variations of the absorbing power, according to the age, the sex, the constitution, and different periods of the day, shew that it cannot be compared, as several physiologists have done, to that principle which makes fluids ascend, contrary to the laws of gravitation, in capillary tubes. If absorption were a process merely mechanical, it would in no case be accelerated or retarded, and would proceed with a regularity never observed in the vital functions. The mouth of every lymphatic, when about to absorb, erects itself, draws towards itself and raises the surrounding membranous parts, and thus forms a small tubercle, similar to the puncta lachrymalia. These little bulgings deceived Lieberkuhn, and led him to think, that the absorbents of the intestines originated from small ampullulæ, or vesicular enlargements, which, as so many exhausted receivers, pumped up the fluid extracted from the food. This physiologist may further have been led into error, by the nervous papillæ of the inner membrane of the canal, swollen by the determination of blood attending irritation, the natural consequence of the friction of the alimentary substances. The inhaling faculty belongs not only to the orifices at the extremity of each radicle, but likewise to the lateral pores, which are infinitely numerous, in the parietes of the vessels.†

* It does not fall to the lot of every one to err like M. Dumas, whose talents and ingenuity I have much pleasure in acknowledging. He imagines rickets to consist in a deficient influence of the nervous system on the bones; which would constitute a kind of paralysis. Anatomy shews the presence of no nerves in the tissue of the bones, and veins and arteries are alone seen to enter the foramina, and no nerves appear to be transmitted through them. The functions of the bones made it unnecessary that they should be endowed with that peculiar sensibility which requires the existence of nerves. The bones are active by being subject to the process of nutrition, but in every other respect they are absolutely passive. In the opinion of some people, such doctrines are real discoveries. *Credat Judæus Apella, non ego.*

† See APPENDIX, Note Q.

XLIII. *Anastomoses, distribution and course of lymphatics.*—After arising on the surface, and in the interior of the body, by radicles in close contact, the lympathetics creep and coil themselves, describe numerous curves, unite, then divide, and presently unite again,—and from these numerous inosculations, there results a net-work, with close meshes, forming, with that of the blood-vessels, the texture of the cellular tissue and of the membranes.

Each lamina of cellular tissue is, in the opinion of Mascagni, nothing but a mesh-work of lymphatics ; the texture of the membranous and transparent tissues, as the pleura and the peritonæum, resembles that of the laminæ of the cellular tissue : in fine, the same vessels form the basis of the mucous membranes which line the internal parts of the alimentary canal of the trachea and urethra. The Italian anatomist succeeded in filling with quicksilver all the tissues which he considered as lymphatic ; but Ruysch, in his admirable injections, reduced all the membranes, and the laminæ of the adipose tissue, into a net-work purely arterial, of which the meshes were so very closely united as to leave spaces that could scarcely be perceived by the microscope ; and from his preparations he inferred, that arterial capillary vessels, singularly divided and convoluted, form the basis of cellular and membranous tissues. To satisfy one's self, that neither the pleura nor the peritonæum are formed as Mascagni or Ruysch imagined, one need only consider, that arterial exhalation and lymphatic absorption take place from the whole extent of the internal surfaces, and that these two functions prove the existence of both arteries and absorbents in those membranes and in the cellular tissue. The prejudices of those two anatomists, so celebrated, the one by his study of the absorbents, and the other by his beautiful injections of the most minute arteries, are to be attributed to the importance which we are pleased to assign to the objects which particularly engage our attention, and likewise to the distension of the minute vessels by the injection ; these being distended beyond their natural state, compress and conceal the neighbouring parts.

The lymphatics, after emerging from among the cellular substance, unite into trunks sufficiently large to be distinguished from the laminæ of that tissue. These trunks proceed towards certain parts of the body, there they become united to other trunks, follow a parallel course, and frequently communicate together. The lymphatics are not single in their course, as the arteries and veins ; they collect together, form fasciculi of different sizes, some of which are deep-seated and accompany the blood-vessels, while others of them are more superficial, corresponding to the subcutaneous veins of the limbs, and, like them, lying between the skin and the aponeuroses, and in greater number on the inner side of the limbs, in which they are best protected against external injuries. The lymphatics of the parietes of the great cavities, those of the viscera, which these cavities contain, are likewise in two layers, the one superficial, the other deep-seated.*

The absorbents differ likewise from the blood-vessels, in their singularly tortuous course, their frequent communications, and especially in their unequal size in different parts of their extent. An absorbent, of very small dimensions, frequently enlarges, so as to equal in size the thoracic duct, then contracts and again bulges out, though in the length of the vessel in which these differences of size may have been noticed, it may have received no collateral branches. The lymphatics, when completely filled with quicksilver, appear to cover the whole surface of our organs ; and the whole body seems enveloped in a net-work of close and small meshes. The metastasis of humours from one part of the body to another at a distance, is easily un-

* See Appendix, Note Q.

derstood by any one who has seen those numerous inosculations rendered manifest by injection. Metastasis ceases to be an inexplicable phenomenon; one has no difficulty in conceiving how, by means of the lymphatics, all the parts of the body communicate freely; how fluids, absorbed by those vessels in one part, may be conveyed into another, and pervade the whole body, without following the circuitous route of the circulation; and that it is, therefore, not altogether impossible, however improbable, that fluids taken into the stomach may be conveyed directly from the stomach to the bladder, and that pus may be removed from the place in which it is collected, and be carried to the place to which irritation calls it forth. All that Bordeu has said of the oscillations and currents of humours through the cellular texture, in his "*Recherches sur le Tissu muqueux*," may be equally explained by the anastomoses of the lymphatics. The existence of valves in the lymphatic vessels also promotes the circulation of the lymph through them, and renders it impossible for this fluid to flow through them but in one direction. Hence we must necessarily reject the opinions of our predecessors, who supposed it possible that fluids could be conveyed to the urinary bladder, or to the breasts, by means of the retrograde action of these vessels, as stated in the foregoing page.*

A young man whom I had ordered to rub in mercury along the inner part of his left leg and thigh, for the cure of a pretty large bubo, was affected, on the third day, with salivation, though he used only half a dram of ointment at each friction. The salivary glands on the left side were alone swollen, the left side of the tongue was covered with aphthæ, and the right side of the body remained unaffected by the mercurial action: a clear proof, that the mercury had been carried to the mouth, along the left side of the body, without entering into the course of the circulation, and, perhaps, without passing through any of the conglobate glands; for that of the left groin, which alone was swollen, did not sensibly diminish in size. Salivation may, therefore, take place in the cure of the venereal disease, though none of the mercury enter the circulation; which warrants the opinion, that the action of syphilis, as well as of the remedies which are administered for its removal, operates chiefly on the lymphatic system.

XLIV. *Connexion of lymphatics with their glands*.—If the fluids absorbed by these vessels can, in consequence of their numerous inosculations, pervade all parts of the body, without mixing with the blood, not a drop can enter the course of the circulation without having previously passed through the glandular bodies that lie in the course of the lymphatics, dispersed like those vessels in all parts of the body, seldom insulated, but in clusters in the hollows of the ham, the arm-pit, in the bends of the groin and elbow, along the iliac vessels, the aorta, and the blood-vessels of the neck, around the base of the jaw and of the occiput, behind the sternum, along the internal mammary vessels, lastly, within the mesentery, in which their number and size bear a proportion to the quantity of absorbents which pass through them. These reddish glands† varying, in size, of an oval or globular form, have two extremities, one of which is turned towards the part from whence the lymphatics arise, and at which they enter in greater or less number, and are there called "*afferentia*;" and the other extremity turned towards the thoracic duct, which

* For some further remarks on this subject, see APPENDIX, Note Q.

† It is with a view of conforming to the language in common use, that I give the name of gland to those coils of lymphatic vessels which are totally different from the real conglomerate or secretory glands. It might be better, perhaps, to call them *ganglions*, as has been done by my learned and respected colleague Chaussier, though that name is objectionable, from its association in the mind with the nervous ganglions, whose structure is not at all similar to that of the lymphatic ganglions.

sends out vessels, fewer in number but of a larger size, and called "*efferentia*;" from their use.

The lymphatics, on reaching the glands, divide, unite again and inosculate, they likewise bend back on themselves, and thus form the tissue of the conglobate glands, which are merely clusters of coiled vessels, united by cellular tissue, in which blood-vessels are distributed, so as to occasion their reddish colour. The coats of the lymphatics are thinner in the glands than elsewhere; and their dilatations, their divisions, and their anastomoses, are likewise more frequent, while they are embraced in the glandular tissue. All the lymphatic vessels, whose course lies in the direction of a gland, do not enter its substance; several pass by the gland and embrace it, forming around it a sort of plexus, of which the ramifications are directed towards other glands, more in the vicinity of the thoracic duct. The lymphatic glands form so essential a part of the absorbent system, they produce on the lymph such indispensable changes, that no lymphatic vessel enters the thoracic duct without having previously passed through these glands. It even frequently happens, that the same vessel passes through several glands before opening into that common centre of the lymphatic system. Thus, the vessels which absorb the chyle of the intestinal tube pass several times through the glands of the mesentery. The lymphatics of the liver, situated very near to the receptaculum of Pecquet, have been thought, by some anatomists, not to follow that general rule; but there are uniformly found, in the course of these vessels, glands which they enter. As, however, the glands are few in number, the lymph conveyed from the liver is only once subjected to the action of the glands; and this circumstance appears to me to explain, in a satisfactory manner, the transmission of the colouring matter of the bile, which, in jaundice, manifestly discolours the blood, in which M. Deyeux found it by chemical analysis.

XLV. *The structure and functions of the lymphatics.*—The parietes of the lymphatic vessels are formed of two coats, both very thin and transparent, yet very strong, since they support the weight of a column of mercury, which would rupture the coats of arteries of the same calibre. The internal coat, which is the thinner of the two, forms valvular folds, arranged in pairs, like the valves of the veins, and, like them, preventing a retrograde circulation. Although these coats are very strong, and likewise very elastic and contractile, as they may be seen to contract, and to expel the lymph with great impetus, when the abdomen of a living animal* is laid open, yet the course of the lymph is far from being as rapid as that of the blood; it even frequently appears affected with irregular oscillations, such as are to be met with in the circulation of the blood through the capillary arteries. The numerous dilatations, curvatures, and anastomoses of the absorbents must, in a considerable degree, impede the rapid progress of the lymph, but the circulation must be retarded, chiefly in the glands, as there the vessels are most convoluted, dilated, and form the greatest number of anastomoses and are most subdivided. Besides, the parietes of the absorbents are thinnest in their passage through the glands, for these may be ruptured by the weight of a column of mercury, which the vessels themselves are able to support.

* In some cases, the activity of the absorbents appears increased in a singular degree. Thus jaundice has been known to be the immediate consequence of a wound of the liver; and on other occasions, a metastasis of humours has taken place with the utmost rapidity. I suspect that, in such cases, the substance that has been absorbed circulates by means of the anastomoses, and pervades the lymphatics with which the whole body is covered, but without passing through the glands, which would slacken its course, and, to a certain degree, alter its nature.

And the action of these vessels, naturally weaker in that situation, is still farther diminished by the close, cellular adhesion which unites together the vessels whose union forms the glandular bodies.

It was necessary that the course of the lymph should be slackened in its passage through the glands, in order that it might undergo all the changes which those organs are to produce upon it. Although we do not know precisely what those changes are, their object appears to consist in a more perfect union and combination of its elements, and in bestowing on it a certain degree of animalisation, as is seen by the greater tendencies to coagulation of the fluid taken from the vasa efferentia. Another object of the passage of the lymph through the glands, appears to be to deprive it of its heterogeneous particles, or at least to alter their nature, so that they may not become injurious when they get into the mass of the fluids. The yellow colour of the glands through which the absorbents of the liver pass, the dark colour of the bronchial glands, the red colour of the mesenteric glands, in animals which have been fed on madder or beet-root, the whiteness of the same glands, while the chyle is passing through them, are circumstances which shew, that the glands separate, or tend to separate, the colouring matter of the lymph, and that if they do not effectually prevent its transmission into the blood, it is because certain colours, as indigo and madder, have too much tenacity, while other substances, as the bile, do not pass through a sufficient number of glands to lose their colour entirely. The blood-vessels, which are very numerous in the tissue of the conglobate glands, pour into the lymphatics a serous fluid, which dilutes the lymph, increases its quantity, and at the same time animalises it. The number of the lymphatic glands is very great; many are so small as to escape the eye, but become enlarged and visible in certain cases of disease. I have daily opportunities of observing in scrofulous patients swollen glands, in situations in which anatomists have not pointed out any. The absorbent glands are at no time so large or numerous as in infancy. They very frequently disappear in old people, and it is difficult to say, whether they have been totally destroyed, or whether they are merely exceedingly reduced in bulk.

XLVI. *Morbid states of the absorbent glands.*—The frequent congestions of the conglobate glands depend on the stagnation of the lymphatic fluid in their substance, and on the comparative weakness of the sides of the vessels in these parts. The influence of debilitating causes on the lymphatic system acts most powerfully on the glands, which are the weakest part of that system. In such cases, the vessels which enter into the composition of the glands act feebly, or cease to act altogether; the fluids, of which there is a continual accession, accumulate; the most liquid part alone penetrates through the glandular organ, the grosser particles remain, the humour thickens, hardens, and forms congestions of various kinds. If there is a tendency to cancer, such tumours, at first indolent, become painful; the more inspissated matter being, in a manner, out of the influence of the vital power, since its vessels are in a state of complete atony, undergoes a sort of putrid fermentation, the consequence of which is a destruction and erosion of the cellular tissue, attended by inflammation of the skin and neighbouring parts. The tumour becomes an abscess, and discharges matter rendered liquid by the process of fermentation, and so acrid and irritating, that it extends the affection towards all the parts with which it comes in contact.

The notions entertained hitherto on cancer are, at once, deficient in precision and accuracy; and it is to their fallacy that we are to attribute the number of contradictory opinions on the subject of its proper treatment. Too precise a distinction cannot be laid down between the cancerous or phagedenic

ulcer, whose seat is always in the skin, or in the mucous membranes (which being mere prolongations of the skin, retain much of its structure), and those cancers which affect the other parts of the animal economy, especially the lymphatic glands, the testicles, and the breasts. In the cancerous ulcers, peculiarly frequent in the face, the lips, the tongue, in the inner coat of the stomach, of the rectum, and of the uterus, the parts affected with inflammation of a malignant kind are destroyed, without any means of checking the progress of that destructive action, the cause of which is easily conceived; while in true cancer, the glandular tumefaction always precedes the cancerous diathesis. As long as the affection consists merely in the obstruction of the vessels by indurated lymph, the tumour is indolent, and is yet only a scirrhus; but soon all trace of organisation is lost in the tumefied part, the ruptured vessels are lost in the mass of different substances; the process of fermentation which takes place, converts every part into a grayish pulpy substance, in which the most expert eye can discover no organisation, and no distinction of parts. Whenever this cancerous destruction of parts occurs, whether the whole organ is affected, or whether the disease extends only to a few points, extirpation is the only remedy to be employed; it is absolutely necessary that a surgical operation should rid the constitution of a part in which organisation and life no longer exist.

The lymphatic glands, which swell in the vicinity of cancerous tumours, have already received, by means of the absorbents, the destructive germ, and must be removed, with the rest of the diseased part, that the operation may be attended with the greater prospect of success. It is very true, that open cancers of the breast may, for a long time, discharge putrid matter, without inducing a cancerous affection of the glands of the axilla. But may not the discharge, in this case, act on the principle of revulsion? and besides, what shall we oppose to experience, which shews that these glands, if not removed along with the cancerous breast, soon becomes affected with cancer? If the nature of this work did not circumscribe me within certain limits, I should point out several other particulars relative to the history of cancer; and, among other cases, in my own practice I should relate that of a woman, in whom I removed a cancerous tumour situated on the left side of the chest: this case is remarkable from the number of operations which her disease required, and for which M. Pelletan removed, six years ago, the left breast, and three years ago a gland under the axilla of the same side.

The difference in the termination of glandular swellings and those arising from cancer, scrofula, or syphilis, makes it probable that there exist ferments, or specific poisons, which dispose the accumulated matter to undergo peculiar changes.

The venereal virus, absorbed by the lymphatics of the organs of generation, remains for some time in the glands of the groin, before it extends beyond, as is proved by the cure of the venereal disease by extirpating the diseased glands. In short, the impediment which the lymph meets with in passing through the glands, shews why these parts are so frequently the seat of critical abscesses, by which we judge of the nature of several fevers of a malignant kind. In the plague of Eastern countries, the virus that occasions this dreadful malady is disseminated throughout the body, collects in the glands, is transmitted through them with difficulty, brings on an irritation and gangrenous inflammation, terminating in pestilential buboes.

XLVII. *Of the thoracic duct.*—The thoracic duct may be considered as the centre in which the lymphatic system terminates; it arises at the upper part of the abdomen, from the union of the chylous vessels with the lymphatics coming from the inferior extremities. At the part where all these

vessels meet, there is a dilatation, a sort of ampullula, called lumbar cistern, receptaculum chyli, or of Pecquet, which, in truth, is not always found, and the size of which is very variable. The thoracic duct enters the chest through the opening in the diaphragm through which the aorta passes; it then ascends along the spine, on the right side of the aorta, within the posterior mediastinum. At the upper part of the chest opposite to the seventh cervical vertebra, it inclines from the right to the left side, passes behind the œsophagus and the trachea, and opens into the subclavian vein of the left side, at the back part of the insertion of the internal jugular into that vein. While the thoracic duct is ascending along the spine, it receives the lymphatics of the parietes of the chest; those of the lungs enter it as it passes behind the root of these organs. In its course from the right towards the left side, it receives the absorbents of the right upper extremity, and those of the right side of the head and neck. Lastly, it unites with those vessels which are coming from the left side of the head and neck, as well as from the left upper extremity, just before opening into the subclavian vein. The thoracic duct sometimes has its insertion in the jugular vein of the same side, and not unfrequently the lymphatics of the right side of the chest, neck, and head, and of the right upper extremity, unite to form a second duct, which opens separately into the right subclavian vein.* Whatever be the vein into which the duct opens, its structure is the same as that of the lymphatics, and its inner part is furnished with valvular folds. Its increase of size is not progressive as it approaches towards its termination; on the contrary, there are seen, here and there, dilatations of different sizes, separated by proportionate contractions. Sometimes it divides into several vessels, which inosculate and form lymphatic plexuses. The opening at which the thoracic duct enters the subclavian vein is furnished with a valve, better calculated to prevent the flow of blood into the lymphatic system, than to moderate the too rapid flow of the lymph into the torrent of circulation. Compression of the thoracic duct, in aneurism of the heart and aorta, gives rise to several kinds of dropsy,—a disease always depending on the loss of equilibrium between the processes of inhalation and exhalation, either from increased action of the exhalants, or from the absorbents refusing to take up the lymph, in consequence of obstruction in the glands, or of compression of the duct.

XLVIII. *Of the nature of the lymph and chyle.*—The nature of the lymph is far from being as well understood as that of the vessels along which it circulates. Haller considers it as very analogous to the serum of the blood, and says that this substance, to which he frequently gives the name of lymph, is, like the fluid contained in the absorbents, slightly viscous and saltish; that heat, alcohol, and the acids coagulate it; in short, that it possesses all the qualities of the albuminous fluids. The serum of the blood exhaled, throughout the extent of the internal surfaces, and even within the substance of our organs, by the capillary arteries, is absorbed by the lymphatics, and is one of the principal sources of the lymph, which resembles it much. It may be conceived, however, that the lymph must be much more compound than the serum of the blood, since the lymphatics which absorb, almost indiscriminately, every kind of substance, take up what comes off from our organs, and the recrementitious parts of our fluids, and these, when marked

* In some cases, lymphatic vessels, in other parts of the body, are seen to open into neighbouring veins. This enables one to account for the presence of the chyle which is said to have been found in the meseraic veins, into which it had been poured by some lacteal. Mascagni was aware of this anatomical fact. The lymphatic system is, however, the most subject to deviations of any in the animal economy.

See APPENDIX, Note Q, for later observations connected with the subject matter of this note.

by striking qualities, are sometimes recognisable in the absorbents,—as fat, by its not mixing with aqueous fluids—and bile, by its deep yellow colour.

The chyle, which is necessarily affected by the various kinds of food which we use, has different appearances in the same persons, varying according to the quality of the different substances on which we feed: indigo gives it a blue colour; it is reddened by madder and beet-root; and is changed to green by the colouring matter of several vegetables, &c. In a great number of experiments performed on living animals, it has always appeared to me such as it is described by authors, white, with a slight viscidity, and very like milk containing a very small quantity of flour. It is easy to collect a certain quantity of chyle, by tying the thoracic duct of a large dog, of a sheep, or even of a horse, as was done several times at the veterinary school at Alfort. This fluid, when exposed to the air, on cooling, separates into two parts, the one forming a kind of gelatinous coagulum, very thin and not unlike the buffy coat of inflammatory blood; the other, in greater quantity and liquid, rising above the coagulum, on its being detached from the sides of the cup, to which it adheres. The coagulated mass is semi-transparent, of a light pink colour, does not resemble the curd of milk; so that all that has been said by a few modern physiologists, the exact resemblance which they have pretended to discover between milk and chyle, is totally void of foundation.*

The lymph, which constantly unites with the chyle before the latter enters the sanguiferous system, on being received into a vessel by Mascagni, coagulated in the space of seven or ten minutes, turned sour, and soon separated into two parts, the one more abundant, serous, in the midst of which there floated a fibrous coagulum, which by contracting formed into a small cake on the surface of the fluid. Hence he concludes, contrary to the opinion of Hewson, that lymph consists, for the greatest part, of serum, and that fibrine constitutes its least part.

XLIX.—The practice of surgery in a great hospital has afforded me frequent opportunities of examining the lymph which is discharged, in abundance, from ulcerated scrofulous tumours in the groin, in the axilla, and in various other parts of the body. I have always met with a liquid nearly transparent, slightly saline, coagulable by heat, alcohol, and the acids. Small fibrous flocculi form, even on the surface of the cloths which are wetted with it, and shew the existence of two parts; the one a gelatino-albuminous fluid holding in solution several salts; the other, in smaller quantity, is a fibrous substance which concretes spontaneously. The lymph in man and the warm-blooded animals appears to me in every respect similar to the fluid which is contained in the vessels of white-blooded animals.†

* According to the analysis of the chyle performed by Dr. Marcet, and published in the sixth volume of the Transactions of the Medico-Chirurgical Society, this fluid presents very different properties according as it is the product of vegetable or animal food. When it proceeds from vegetable diet, it contains much more carbon, and may be preserved a much longer time, without undergoing putrefaction, than that which is the product of animal food. The former, also, is nearly transparent, whilst the latter is milky, very putrescent, and, besides albumen, contains an oily matter resembling cream, and furnishes much carbonate of ammonia by distillation. Neither kind of chyle contains gelatine, which seems to be replaced, whatever may be the nature of the food, by albumen.—*J. C.*

† See Appendix, Note Q.

CHAPTER III.

OF THE CIRCULATION.

L. The Circulation defined, and its Uses stated.—LI. Of the Structure and Action of the Heart.—LII. and LIII. Of the Mechanism of the Circulation through the Heart.—LIV. Of the Action of the Arteries.—LV. Of the Structure of the Arteries.—LVI. Of the Formation of Aneurisms.—LVII. Of the Action of Arteries.—LVIII. and LIX. Of the Pulse.—LX. Of the Capillary Vessels.—LXI. Anastomoses and Properties of the Capillaries.—LXII. Of the Actions of the Veins.—LXIII. to LXV. Of the Venous Circulation, &c.—LXVI. and LXVII. Of the general, greater, or systemic Circulation.—LXVIII. Of the Pulmonary or lesser Circulation.

L.—The term *circulation* is applied to that motion by which the blood setting out from the heart is incessantly carried to all parts of the body by means of the arteries, and returns by the veins to the centre whence it began its circuit.

The uses of this circulatory motion are to expose the blood, changed by mixing with the lymph and the chyle, to the air in the lungs (*respiration*); to convey it to several viscera, in which it passes through different steps of purification (*secretions*); and to send it into the organs whose growth is to be promoted, or whose losses are to be repaired, by the nutritive and animalised part of the blood brought into a state of perfection by these successive processes (*nutrition*).

The circulatory organs are less useful in elaborating than in conveying the fluids. To form a just conception of their uses, one may compare them to those workmen in a large manufactory in which various kinds of goods are made, who are employed in carrying the materials to those who are to work them; and as among the latter some finish the work, while others prepare the materials, so the lungs and the secretory glands are continually occupied in separating from the blood whatever is too heterogeneous to our nature to become assimilated to our organs, or to afford them nourishment.

To understand thoroughly the mechanism of this function, it is necessary to study separately the action of the heart, that of the arteries which arise from it, and, lastly, that of the veins which enter it. The union of these three classes of organs forms the circle of the circulation.

LI. *Of the structure and action of the heart.*—In man and in all warm-blooded animals the heart is a hollow muscle, the inner part of which is divided into four large cavities which communicate with one another; from these, vessels arise which convey the blood to all parts of the body, and the vessels which bring it back from all those parts likewise terminate in these cavities.

The heart is placed in the chest, between the lungs, above the diaphragm, whose motions it follows; it is surrounded by the pericardium, a dense and fibrous membrane admitting of very slight extension, closely united to the substance of the diaphragm, covering the heart and great vessels, without containing them in its cavity, furnishing an external covering to the heart, and bedewing its surface with a serous fluid which, never accumulating, except in disease, facilitates its motion and prevents its adhering to the neighbouring parts. The principal use of the pericardium is to fix the heart in its place, to prevent its being displaced into other parts of the chest, which could not happen without occasioning a fatal disorder in the circulation. If, after having laid open the chest of a living animal, by raising the sternum, an incision is made into the pericardium, the heart protrudes through the opening, and moves to the right and left by bending itself on the origin of the large vessels;

the course of the blood is then intercepted, and the animal threatened with immediate suffocation.*

In man, the heart is placed nearly towards the union of the upper third of the body with the lower two-thirds; it is, therefore, nearer to the upper parts; it holds them under a more immediate control; and as that organ keeps up the action of all the rest, by the blood which it sends into them, the parts above the diaphragm have much more vitality than the parts beneath. The skin of the upper part of the body, and especially of the face, has more colour and is warmer than that of the lower parts; the phenomena of diseases come on more rapidly in the upper parts; they are, however, less liable to put on a chronic character.

The bulk of the heart, compared to that of other parts, is larger in the fœtus than in the child that has breathed, in short men than in those of high stature. The heart is likewise larger, stronger, and more powerful, in courageous animals than in weak and timid creatures.

This is the first instance of a moral quality depending on the original conformation of parts; it is one of the most striking proofs of the influence of the moral character of man on his physical nature. Courage arises out of the consciousness of strength, and the latter is in proportion to the activity with which the heart propels the blood towards all the organs. The inward sensation occasioned by the afflux of the blood is the more lively and better felt when the heart is powerful. It is on that account that some passions,—for example, anger,—by increasing the action of the heart, increase a hundred fold both the strength and courage; while fear produces an opposite effect. Every being that is feeble is timorous, and shuns danger, because an inward feeling warns him that he does not possess sufficient strength to resist it. It may perhaps be objected, that some animals, as the turkey-cock and the ostrich, possess less courage than the least bird of prey, that the ox has less than the lion and other carnivorous animals. What has been said does not apply to the absolute, but to the relative size of the heart. Now, though the heart of a hawk be absolutely smaller than that of a turkey-cock, it is nevertheless larger in proportion to the other parts of the animal. Besides, the bird of prey, like the other carnivorous animals, in part owes his courage to the strength of his weapons of offence.

Another objection, more specious, but not better founded, is drawn from the courage manifested on certain occasions by the most timid animals; for example, by the hen in protecting her young; from the courage with which other animals, pressed by hunger or lust, surmount all obstacles; but particularly from the heroic valour of men of the most feeble bodies. All these facts, however, are only proofs of the influence of the mind on the body. In civilised man, the prejudices of honour, interested considerations, and a thousand other circumstances, degrade his natural inclinations, so as to make a coward of one whose strength is such as would induce him to brave all kinds of danger; while, on the other hand, men whose organisation should render them most timid, are inspired to perform the most daring actions. But all these passions, all these moral affections, operate only by increasing the action of the heart, by increasing the frequency and the force of its pulsations, so that it excites the brain or the muscular system by a more abundant supply of blood.

The heart is not quite so ovoid in man as it is in several animals, nor is it parallel to the vertebral column, but it lies obliquely, and is flattened towards the side next the diaphragm on which it rests.

* For some remarks on the intimate connexion, owing to the above conformation, subsisting between the Functions of Respiration and Circulation, see APPENDIX, Notes R and U.—*J. C.*

Of the four cavities which form the heart, two are, in a measure, accessary, viz. the auricles: they are small musculo-membranous bags opposed to each other, receiving the blood of all the veins, and pouring that fluid into the ventricles, at the base of which the auricles are, as it were, applied. The ventricles are two muscular bags separated by a partition of the same nature, and belonging equally to both: they form the greatest part of the heart, and give origin to the arteries.

The auricle and ventricle on the right side are larger than those on the left. But that difference of size depends as much on the manner in which the blood circulates at the approach of death, as on the original conformation of the lungs. On the point of death, the lungs expand with difficulty, and the blood sent into them by the contractions of the right ventricle, being no longer able to circulate through them, collects in that cavity, flows back into the right auricle, in which the veins continue to deposit blood, stretches their parietes, and increases considerably the dimensions of those cavities. The capacity of the right cavities is, however, originally greater than that of the left, and is proportioned to that of the venous system which opens into them. The right cavities of the heart, which might be called its venous cavities, have likewise thinner parietes than the left or arterial, and in this respect the same difference is observed as in the parietes of the arteries and veins. The right ventricle, having to send the blood destined to the lungs to a very short distance, and through a tissue easily penetrated, requires but a moderate impelling force.

As will be shewn, in speaking of respiration, a function of which the physiological history is not easily separated from that of the circulation, the heart may further be considered as formed of two parts in contact, the one right or venous, the other left or arterial. Notwithstanding the juxta-position of these two parts of the same organ, they are perfectly distinct, and the blood in each cavity is very different from that in the other. The blood in the adult can never pass immediately from the one to the other: the right side of the heart receives the blood of the whole body, and transmits it to the lungs; the left side of the heart receives the blood of the lungs, and distributes it over the whole body; so that, in a physiological point of view, the lungs form a part of the circle of the circulation, and serve as an indispensable medium between the two divisions of the heart; and, as will be seen hereafter, their part of the circle is by no means the least important.

If there existed between the ventricles a direct communication, the venous blood would mix with the arterial, and the union of these two fluids would mutually impair the qualities of each. Recent observations have furnished an opportunity of judging of the effects of such a communication between the ventricles, which had been imagined by the ancients, but of which no case had yet been met with. A man, forty-one years of age, came to the Hôpital de la Charité, to undergo the operation of lithotomy. He was remarkable for the lividity of his complexion, the turgescence of the vessels of the conjunctiva, and the thickness of his lips, which, like the rest of his face, were of a dark colour; his respiration was laborious, his pulse irregular; he could not utter two words in succession without taking breath, was obliged to sleep in a sitting posture, and was particularly remarkable for his indolence. This indolence, joined to great simplicity of nature, was such, that he had never been able to maintain himself without the assistance of his wife. A very small quantity of blood was taken from his arm, in consequence of which his pains were diminished, but his difficulty of breathing increased, was followed by syncope, and he died from suffocation. On opening his body, his heart was found filled with blood, and especially the right auricle, which was con-

siderably distended; the pulmonary artery was aneurismal, and uniformly distended from the right ventricle to its division; none of its coats had yet given way. The two ventricles of the heart were of nearly the same capacity, and the relative thickness of their parietes did not vary so much as in health. The partition between them contained an opening of communication of an oblong shape, about half an inch in extent, and directed obliquely from below upwards, from before backward, and from left to right; so that, not only the direction of the opening, but likewise a kind of valve, formed in the right ventricle by a fleshy column, so placed as to prevent the return of the blood into the left ventricle, clearly shewed that the blood flowed from the left into the right ventricle, and thence into the pulmonary artery. The ductus arteriosus, an inch in length, and large enough to admit a goose quill, allowed, as in the fœtus, a free passage to the blood, from the pulmonary artery into the aorta. The foramen ovale was closed.

This singular conformation explains, in the most satisfactory manner, the phenomena observed during the life of the patient, and the organic affection of the pulmonary artery. There was necessarily in this vessel a mixture of venous and arterial blood, and this blood was sent into it in part by the action of the left ventricle, with an increased impetus, which accounts for the aneurism. The blood which reached the lungs was already vivified, and required less action from that organ to complete its oxydation; on the other hand, the right auricle emptied itself, with difficulty, into the right ventricle, in part filled with the blood which the left ventricle sent into it with greater force: hence the extreme difficulty in the venous circulation, the lividity of the complexion, the colour and the puffiness of the face, and the habitual and general torpor. This state of languor and inactivity might likewise depend on the flow of the venous blood into the aorta along the ductus arteriosus. It is worthy of observation, however, that this impure blood was not transmitted to the brain, whose vital excitement it would not have been able to maintain. The lower extremities bore no proportion to the upper, and this inequality, analogous to what is observed in the fœtus, depended on a similar cause. The morbid preparation made from this person was deposited by M. Deschamps in the museum of the Ecole de Médecine of Paris, and was, by their desire, modelled in wax. M. Beauchêne, junior, presented the same museum with a similar preparation, which he procured from a subject in the dissecting-room.

Several anatomists have paid attention to the structure of the heart; much has been said on the subject of the peculiar arrangement of the muscular fibres which form its parietes; yet the only result that can be obtained from all these researches is, that it is absolutely impossible to unravel the intricacy of these fibres.* Fibres of the ordinary structure, and crossing each other in

* On this point the author is by no means correct. The structure of the heart may be demonstrated with tolerable accuracy. The latest and most correct description of it has been furnished by J. F. Vauss, teacher of anatomy in the University of Lieges.

As an accurate view of the distribution of its fibres is requisite to enable us to know the nature of the actions of this viscus, the following account by this anatomist is here introduced:—

"The heart is a conical hollow muscle, covered by a serous (fibro-serous) membrane, the pericardium,—lined by a membrane, which is of a different nature in each ventricle, and composed of three layers of muscular fibres,—the superficial one common to both ventricles—the middle one at least four times as large as the preceding, and, like it, common to the two great cavities of the heart,—and the lower one divided into two parts, the right and the left, each belonging to the corresponding ventricle; both of them forming the septum by their junction, and giving birth to the carneæ columnæ.

"The other layer is very fine; its bundles of fibres, which become more oblique as they get lower, are directed, the anterior ones from the right to left, and the posterior ones from left to right, from the base to the apex of the heart, where they are confounded with the fibres of the middle layer.

"The fibres of the middle layer are much more numerous, and follow the same direction; only they are more oblique, and are not all of them carried to the apex of the heart. The inferior fibres only reach the apex, and are there confounded with the fibres of the outer layers;

various directions, form the two auricles; other and more numerous fibres form the parietes of the ventricles, reach from the apex to the base, extend into the septum which divides them, pass from the one to the other, and are lost in each other in several points. They are exceedingly red, short, close, and united by a cellular tissue, in which fat scarcely ever accumulates.

These fibres, forcibly pressed against each other, form a tissue similar to the fleshy part of the tongue, endowed with but little sensibility, but contractile in the highest degree. Vessels and nerves, in considerable number, if compared to the bulk of the heart, pervade this muscular tissue, whose contraction, whatever in other respects may be the direction of its fibres, tends to draw towards the centre of the cavities every point of their parietes. Lastly, a very fine membrane lines the inner part of these cavities, facilitates the flow of the blood, and prevents the infiltration of that fluid.

LII. *Of the circulation through the heart.*—If we suppose, for a moment, that all the cavities of the heart are perfectly emptied of blood, and that they are filled in succession, the following may be considered as the mechanism of the circulation through the heart. The blood brought back from every part of the body, and deposited into the right auricle by the two venæ cavæ and by the coronary vein, separates its parietes, and dilates it in every direction. The irritation attending the presence of the blood stimulates the auricle to contraction: this fluid, which is incompressible, flows back in part into the veins, but it chiefly passes into the pulmonary ventricle through a large aperture, by means of which it communicates with the right auricle. The auricle, after freeing itself of the blood with which it is filled, relaxes and again dilates by the accession of a new supply of this fluid, continually brought by the veins which open into it.

whilst the others, according as they become more superficial, reach the posterior furrow, where the layer untwists itself, to form the two unequal portions which compose the lower layer of each ventricle.

"The lower layer of the right ventricle, which is much thinner than that of the left, separates itself from the latter on a level with the posterior furrow, and is carried backwards on the outside before, and then within the ventricle which it immediately envelopes. All its bundles bend from below upwards, and crossing the direction of those of the middle layer, are fixed, the upper ones, which are almost transverse, to the circumference of the auriculo-ventricular opening, and to the anterior part of the mouth of the pulmonary artery; the others, which are longer and more oblique, and which form the right side of the septum, successively to the part of that orifice which is between the two ventricles, and to its posterior part.

"The lower layer of the left ventricle, which is much thicker than that of the right, arises, like it, from the middle layer, on a level with the posterior furrow. Its bundles run from behind to before, between the two cavities, thus forming the left side of the septum; reach the anterior furrow; then, running from right to left, and from below upwards, they surround the ventricles; and crossing the line of the bundles of the middle layer, are fixed successively, one by the side of the other, to the origin of the aorta, and to the opening of communication between the ventricle and auricle, all the way to the upper extremity of the posterior furrow.

"The lowest bundles on each side alone follow a different direction. These bundles, after separating from the others, approach the centre of the corresponding ventricle, and form the carneæ columnæ of the heart.

"Thus, all the fibres of the superficial layer assume the form of a lengthened spiral, which takes a direction from the base towards the apex of the heart, where the fibres are confounded with those of the middle layer, after having made a turn, or a turn and a half. Those of the middle layer have the same form, the same general direction, and the same origin; but they are more oblique, and are so arranged that one part only of them reach the apex of the heart, whilst the greater part terminate at its posterior furrow. Those of the last layer of each ventricle have still a spiral form, but the screw takes the inverse direction; for the fibres stretch from the posterior furrow to the base of the heart, and they do not reach that part until they have surrounded the corresponding ventricle from right to left, crossing the line of the fibres of the two other layers. The septum is formed by the junction of the two lower layers, with the addition of a few bundles, which run from the apex of the heart, and appertain to the middle and superficial layers, which are mixed together at that part.

"The structure of the auricles is less regular. In general, the fleshy fibres pass from the circumference of the mouths of the veins, and from the auriculo-ventricular opening, to be distributed over the parietes, and especially on the septum; where, in the situation of the fossa ovalis, they form two crescents, the concave parts of which are opposed to each other."

For remarks on the Functions of the Heart, see APPENDIX, Note R.—*J. C.*

However, the right ventricle, filled with the blood which it has received from the auricle, contracts in its turn on the fluid whose presence excites its parietes, and tends, in part, to return it into the right auricle, and to send it along the pulmonary artery. Regurgitation from the ventricle into the auricle is prevented by the tricuspid valve, a membranous ring surrounding the edge of the opening of communication, the free edge of which is divided into three divisions, to which are attached small tendons terminating in the columnæ carneæ of the heart. The valves, laid against the parietes of the ventricle the instant the blood passes into its cavity, recede from them when it contracts, and rise towards the auricular opening. They cannot be forced into the auricle, as their free and loose edge is kept in its situation by the columnæ carneæ, which are like so many little muscles, whose tendons, inserted into the loose edges of the valves, bind them down when the stream of blood tends to force those membranous folds towards the auricles. The three divisions, however, of the tricuspid valve, by rising towards the auricular aperture, return into the auricle all the blood contained in the inverted cone which they form immediately before rising. Besides, these three portions of the tricuspid valve do not close completely the aperture around which they are placed; they are perforated by a number of small holes: a part of the blood, therefore, returns into the auricle, but the greatest portion is sent into the pulmonary artery. The action of this vessel begins when the parietes of the ventricle are in a state of relaxation; and the blood would be forced back into the ventricle, if the sigmoid valves, by rising suddenly, did not prevent it. Supported on a kind of floor, formed by three valves, which lie across the calibre of the vessel, the blood pervades the tissue of the lungs, and flows along the divisions of the pulmonary vessels; from the arteries it passes into the veins, and these, four in number, return it into the left auricle. This auricle, stimulated by the presence of the blood, contracts in the same manner as the right; part of the blood flows back into the lungs, but the greatest part enters the left ventricle, which sends it along the aorta to every part of the body, whence it returns again to the heart by the veins. The regurgitation of the blood into the left auricle is prevented by the *mitral* valve, which is similar to the *tricuspid*, except that its loose edge is divided only into two divisions. As soon as the blood has reached the aorta, this vessel contracts, its sigmoid valves fall, and the blood is sent to every part of the body, which is supplied by some of the innumerable branches of that great artery.

In a natural state, the circulation is not carried as has been just stated; and we have supposed this successive action of the four cavities of the heart, only to render more intelligible the mechanism of the circulation in that organ. If we lay bare the heart in a living animal, we observe that the two auricles contract at the same time, and that the contraction of the ventricles is likewise simultaneous, so that while the auricles are contracting, to expel the blood which fills them, the ventricles are dilating to receive it. This successive contraction of the auricles and ventricles is readily explained, by the alternate application of the stimulus which determines the action of these cavities. The blood which the veins bring into the auricles does not excite their contraction till a sufficient quantity has been collected. While this accumulation is taking place, they yield, and the resistance which is felt on touching them, during their diastole, depends, almost entirely, on the presence of the blood which separates and supports their parietes.* The same applies to the ventricles; they cannot contract until a sufficient quantity of blood is collected within them: that there remains some blood in these cavi-

* See the APPENDIX, Note R, for some recent opinions and experiments on this subject.—J. C.

ties, (for they are never completely emptied,) is no objection to the theory, since this small quantity is not sufficient to bring on contraction of the heart, and is not worth taking into account.

If I am asked why the four cavities of the heart do not all contract at once, I answer, that it is easier to assign the final than the proximate cause. If the contraction of these cavities had been simultaneous instead of being successive, it is evident that the auricles could not have emptied themselves into the ventricle. The alternate action is, moreover, absolutely necessary, as the heart, any more than the other organs, is unable to keep up a perpetual action; the principle of its motion, which is soon exhausted, being incapable of restoring itself except during rest. But, as was observed at the beginning of this work, in speaking of the vital power and functions, the alternations of action and repose in organs which, like the heart, perform functions essential to life, must be extremely short in their duration, and at very close intervals.

The cavities of the heart, however, are not entirely passive during dilatation, and the action of that organ does not wholly depend on the excitement of the blood on its parietes, since the heart, after it has been torn from the body of a living animal, palpitates, its cavities contract and dilate, though quite emptied of blood, and appear agitated by alternate motions, which become fainter as the part gets cold. If you attempt to check the diastole of the heart, this organ resists the hand which compresses it, and its cavities appear endowed with a power which Galen termed *pulsive*, in virtue of which they dilate to receive the blood, and not because they receive it. In that respect the heart differs essentially from the arteries, whose dilatation is occasioned by the presence of the blood, whatever some physiologists may have said to the contrary. I have repeated, but unsuccessfully, the famous experiment by which it is attempted to be proved that these vessels have the power of moving independently of the presence of the blood. An artery, tied and emptied of blood, contracts between the two ligatures, and is no longer seen to move in alternate contractions.

LIII.—The heart manifestly shortens itself, and the base approaches towards the apex during the systole or contraction of the ventricles. If it became elongated, as some anatomists have thought, the tricuspid and mitral valves would be incapable of fulfilling the functions to which they are destined, since the columnæ carneæ, whose tendons are inserted in the edges of these valves, would keep them applied to the parietes of the ventricles. The pulsations which are felt in the interval between the cartilages of the fifth and sixth true ribs, are occasioned by the apex of the heart, which strikes against the parietes of the chest. In the explanation of this phenomenon, it is not necessary to admit the elongation of the heart during its systole; it is sufficient to consider that the base of the heart, in which the auricles are situated, rests against the vertebral column, and that these two cavities, by dilating at the same time, and by their inability to move the vertebræ before which they are situated, displace the heart, and thrust it downwards and forwards. This motion depends, likewise, on the effort which the blood sent into the aorta makes to bring to a straight line the curvature of that artery, which re-acts, and carries downwards and forwards the whole mass of the heart, as it were suspended to it.

The quantity of blood which each contraction of the ventricles sends into the aorta and pulmonary artery, most probably does not exceed two ounces in each of these vessels. The force with which the heart acts on the blood which it sends into them, is but imperfectly known, however numerous the calculations by which it has been endeavoured to solve this physiological

problem. In fact, from Keil, who estimates at a few ounces only the force of the heart, to Borelli, who makes it amount to one hundred and eighty thousand pounds, we have the calculations of Michelot, Jurine, Robinson, Morgan, Hales, Sauvages, Cheselden, &c.; but as Vicq. d'Azir observes, not one of these calculations is without some error, either anatomical or arithmetical: hence we may conclude, with Haller, that the force of the heart is great, but that it is, perhaps, impossible to estimate it with mathematical precision. If we open the chest of a living animal, and make a puncture in his heart, and introduce a finger into the wound, pretty considerable pressure is felt during the contraction of the ventricles.

Those who admit to its full extent Harvey's opinion on the circulation of the blood, and who think with him that the heart is the sole agent of the circulation, over-rate the power of that organ, so as to proportion it to the extent of the course which the blood is to take, and to the number of the obstacles which it is to meet in its way. But, as I am about to state, the blood-vessels should not be considered as inert tubes, in which the blood flows from the mere impulse which it has received from the heart.*

LIV. *Of the distribution, structure, and action of the arteries.*—There is no part of the body to which the heart does not send blood by the arteries, for it is impossible to make a puncture with the finest needle into any of our organs without wounding several of these vessels, and causing an effusion of blood. The aortic arterial system may be compared to a tree, whose trunk, represented by the aorta, having its root in the left ventricle of the heart, extends afar its branches, and throws out on every side its numerous ramifications. The size of the arteries decreases the farther they are from the trunk by which they are given off. Their form, however, is not that of a cone; they are rather cylinders arising from one another, and decreasing successively in size. As the branches given off by a trunk, taken collectively, have a greater diameter than that of the trunk itself, the capacity of the arterial system increases with the distance from the heart; hence it follows, that as the blood is continually flowing from a straiter to a wider channel, its course must slacken. The direction of the arteries is often tortuous; and it is observed, that the arteries which are sent to hollow viscera, as the stomach, the uterus, and the bladder, or other parts capable of contracting, of stretching, and of changing their dimensions every moment, as the lips, are much the most curved, no doubt that they may, by unfolding, give way to the extension of the tissues into which they are distributed. Lastly, the arteries arise from one another, and form, with the branch or trunk from which they are given off, an angle varying in size, but which is always obtuse, and more or less acute towards the branch.

As the arteries recede from their origin, they communicate together; and these anastomoses form arches, two branches bending towards each other and joining at their extremities, as we see in the vessels of the mesentery; sometimes two parallel branches meet at an acute angle, and unite into one trunk; thus the two vertebrals join to form the basilary artery: some communicate by transverse branches, which pass from the one to the other, as is seen within the skull.

In the anastomoses of the first kind, the columns of blood, flowing in contrary directions along the two branches, meet at the point of union, and mutually repel each other; their particles mingle, and lose much of their motion in that reciprocal shock. The blood then follows a middle direction,

* For some observations on the source of the heart's action, and on the experiments and opinions of Le Gallois and Dr. W. Philip, made in order to ascertain it, see the APPENDIX, Note R.—*J. C.*

and enters the branches which arise from the convexity of these anastomotic arches.

When two branches unite to produce a new artery, of a greater calibre than each taken separately, but not so large as both together, the motion of the blood becomes accelerated, because it passes from a more capacious into a straiter channel, and the forces which determined its progression are concentrated into one. Lastly, the transverse anastomoses are well calculated to promote the passage of the blood from the one branch into the other, and to prevent congestion in the parts.

LV. *Structure of arteries.*—The arteries are imbedded in a certain quantity of cellular tissue, are almost universally accompanied by corresponding veins, by lymphatics and nerves, and their coats are thicker in proportion as their calibre is smaller. The experiments of Clifton Wintringham prove, that the parietes are stronger in the small than in the large arteries; hence it is observed, that aneurisms are much less frequent in the former. Their parietes have sufficient firmness not to collapse when the tube of the artery is empty. They are formed of three coats: the external or cellular admits of considerable extension, and appears to be formed by the condensation of the laminæ of the cellular tissue which surrounds the artery, and unites it to the neighbouring parts. The second coat is thicker and firmer, of a yellow colour, and fibrous, and is by some considered as muscular* and contractile, while other physiologists merely allow it to possess a considerable degree of elasticity. The longitudinal fibres, admitted by some authors in the texture of this second coat, cannot be distinguished, and their existence is not necessary to account for the longitudinal retraction of arteries. In fact, this retraction might depend on elasticity; it might likewise be occasioned by the contraction of fibres not absolutely circular nor longitudinal, but spiral, and imperfectly surrounding the vessel, and crossing each other in various directions. This yellow coat, thicker in proportion in the smaller arterial twigs than in the larger branches, and thicker in these than in the trunks, is dry, hard, not capable of much extension, and is ruptured by an effort to which the external coat yields by stretching. Lastly, a third, thin and epidermoid coat lines the inside of these vessels, and seems less calculated to give strength to the parietes of the arteries than to facilitate the flow of the blood, by presenting to it a smooth, even, and slippery surface, continually moistened by a serous exudation from the minute arteries, or *vasa vasorum*, which are distributed between these coats.†

Besides these three coats, the great arteries receive a fourth from the membranes lining the great cavities; thus, the pericardium and the pleura in the chest, and the peritonæum in the abdomen, furnish to the different parts of the aorta an adventitious coat which does not completely surround the vessel.

Of the three coats which form the parietes of the arteries, the fibrous, though thicker than the other two, offers, however, the least resistance. If you take the carotid artery, which for a considerable space does not send off any branches, and forcibly inject into it a fluid, the internal and middle coat will be torn before dilatation has increased by one half the calibre of the vessel. The external coat resists the cause of rupture by dilating, and forms

* If in man and the greater number of animals, the yellow fibres which form this coat differ greatly from muscular fibres, they in the elephant resemble that texture very completely, as I had an opportunity of observing, when I witnessed the dissection of the elephant that died in the year 10, at the Museum of Natural History. Let men of judgment decide whether the analogy is sufficient to warrant our admitting, in the arteries of the human body, the existence of muscular fibres.

† See APPENDIX, Note R, for remarks on the Structure and Action of the Arteries.

a tumour; and it is only by applying a pretty considerable force that it can be ruptured. The experiment is attended with the same success, if performed with air or any other gas. In aneurism, the internal and fibrous coats of the arteries, but more particularly the fibrous, are ruptured at an early stage of the disease, which at that period increases suddenly, in a very rapid manner; and on opening the tumour, it is observed that the sac is entirely formed by the dilated cellular coat. Take an artery of a certain calibre,—for example, the carotid or humeral,—apply a ligature around it, and tighten it with some degree of force. Dissect and take out the vessel, then cut the thread, and examine the place to which it was applied; you will observe that the parietes of the artery are in that part thinner, and formed merely by the cellular coat, which alone has withstood the constriction. Take hold of the two ends of an insulated arterial tube and stretch it, then examine its inner coat, and you will find it torn and cracked in several places, and the parietes of the artery evidently weakened.

LVI.—This want of extensibility in the coats of arteries is the principal cause of aneurism; hence the popliteal artery is so liable to that affection, from its situation behind the knee, whose extension is limited merely by the resistance of the posterior tendons and ligaments: this artery is affected by the jar which takes place through all the soft parts when the leg is violently extended; and being less extensible than the other parts, its inner coat is ruptured, or at least weakened, so as to occasion an aneurism, always rapid in its progress. Of ten popliteal aneurisms which I have seen in different hospitals, eight were ascribed to a violent extension of the ham. In looking over the cases that have been recorded, it will be seen that a considerable number of aneurisms of the aorta have been occasioned by too forcible and too sudden an extension of the trunk in raising a heavy burden.

From the dryness and the frailty of the yellow or fibrous coat of arteries, the application of ligatures to these vessels is attended with a speedy laceration of their tissue; a moderate degree of compression is sufficient to rupture that coat, the external and internal remaining, at the same time, uninjured, provided the constriction be not excessive. Why is the arterial tissue, almost the only one on which ligatures require to be applied, the least fitted of all the organic tissues to bear them? This inconvenience attending the ligature of arteries led Pouteau to prefer tying them so as to include the surrounding soft parts within the ligature, though this process is, in other respects, less eligible. The objections will be obviated by employing flat ligatures, which, by acting on a greater surface of the artery, are less likely to divide the coats of the vessel which will become obliterated at the spot to which the ligature is applied, the more rapidly as the patient is younger and stronger.

I once saw, in a man whose thigh was amputated on account of caries of the knee-joint combined with a scorbutic affection, hæmorrhage attend the fall of the ligatures, which did not come away till nineteen days after the operation; as if the fibrous coat of these arteries, partaking in the debility of the muscular organs, had not preserved a sufficient degree of contractile power to close the cavity of the vessel.

LVII. *Properties of arterial vessels.*—The contractile power of the arteries is in their middle coat; it is greater as this coat is thicker in proportion to the calibre of the artery. Hence, as Hunter observes in his work on the blood and inflammation, the larger arteries are endowed with elasticity merely, while, on the other hand, contractility is very apparent in those of a smaller calibre, and is found complete in the capillary vessels; hence, in the trunks near the heart, the progression of the blood is effected chiefly by the impulse which it

receives from the heart; and, as Lazarus Rivière observed, the circulation of the blood in the large vessels is more an hydraulic than a vital phenomenon. The action of the main arterial trunks near the heart has so little influence on the motion of the blood sent into them by that organ, that the aorta is frequently ossified without affecting the circulation. The aorta is naturally bony in the sturgeon. J. L. Petit, in the case of a bookseller whose leg he had taken off, found all the arteries of a certain calibre in a state of ossification; they were indurated, and, of course, incapable of acting, in the slightest degree, on the column of blood which flowed along them. All these facts seem conclusive arguments in favour of those physiologists who explain, on the principle of elasticity, the contraction of arteries. But however correct this explanation may be with regard to the vessels near the heart, it does not apply to the capillaries; the influence of that organ does not operate on these vessels. One may easily conceive, that the column of blood which, by the impulse it has received in the first instance, has been sent along the whole length of tubes whose sides are ossified, inflexible, and consequently inert, on reaching the extremity of these canals, is, in a manner, again taken up by the vital power residing in the capillary vessels, and circulates from the influence of the action belonging to these vessels. Besides, elasticity, however considerable, merely restores those tissues that have been stretched to the condition in which they were before extension. Elasticity is a kind of reaction, proportionate or relative to the action which precedes it. Why do arteries in the living body contract to such a degree that when empty their canal becomes obliterated, while in the dead body, however perfect the depletion of the arterial system may have been, the cavity of the arteries remains perfectly open? Several physiologists, however, and those among the most modern, consider elasticity as the principal cause of the progression of the blood along the arteries.

As the distance from the centre increases, the circulation slackens, from several causes, and the blood could not reach all the parts of the body, if the arteries, whose vitality increases with their distance from the heart, and as they become smaller, did not propel it to all the organs. The causes which retard the circulation of the arterial blood are, the increased dimensions of the space in which it is contained; the resistance from the curves of the vessels; the friction which it undergoes, and which increases, as, at a distance from the heart, the canals along which it circulates increase in number; and lastly, the deviations the blood meets with in its course from the trunks into the branches, which, coming off sometimes almost at right angles, divert it from its original direction.

Many physiologists have called in question this progressive slackening of the flow of arterial blood; and several among them, who reject entirely the application of the physical sciences to that of the animal economy, have, nevertheless, supported their opinion by a fact taken from hydraulics. To give any certainty to these calculations respecting the impediments to the circulation of the blood in the arteries, it would, they say, be necessary that the arteries should be empty at the instant when they receive the jet of blood sent into them by the contraction of the ventricles. This, however, is not the case; the arteries are always full, the blood flows along all of them with the same degree of velocity. This system of vessels may be compared to a syringe, from which a number of straight and tortuous tubes should arise; each of these would throw out the fluid with an equal degree of velocity, on applying pressure to the piston.

In refuting this doctrine, I must take notice of the manifest contradiction of pretending to exclude absolutely all application of the principles of mecha-

nics to physiology, and the complete application of these principles to the phenomena of the animal economy. This contradiction, however, is not more surprising than that of authors who exclaim against the abuse of modern momenclatures, and who, nevertheless, eagerly embrace every opportunity of adding to it, by assigning new names to such parts as may have escaped the attention of the new momenclators. What resemblance is there between a forcing-pump, whose sides are unyielding, as well as those of the tubes which might arise from it, and the aorta, which dilates every time the blood is sent into it? And again, what resemblance is there between tubes which decrease towards their open extremities, while the space contained in the arterial tube constantly enlarges, from the innumerable divisions of the vessels? Since it is admitted that the course of the blood is slower in the capillary vessels, must not this resistance, opposed to the blood which fills the series of vessels from the capillaries to the heart, be felt more at a greater distance from that organ, &c.? Without this progressive increase of resistance, as the arterial blood is at a greater distance from the heart, this fluid would flow along the arteries, as it does along the veins, without any pulsations; for this resistance, which causes the lateral effort of dilatation effected by the blood on the parietes of the arteries, is the principal cause of the pulse, which belongs only to that set of vessels. A very remarkable difference is observable between the blood which is sent to the toes and that which goes to the mammæ, as I have several times noticed in removing the carious bones of the toes, or in extirpating cancerous breasts: the small arteries of these parts are nearly of the same size, but the jet of blood is much more rapid, and the blood is sent to a much greater distance, when one of the mammary arteries is divided.

The re-action of the arteries on the blood which dilates them, depends not only on the great elasticity of their parietes, but likewise on the contractility of the muscular coat. Elasticity has a considerable share in the action of the larger trunks, while contractility is almost the sole agent in producing the action of the minute arteries. If a finger is introduced into the artery of a living animal, its parietes compress it in every direction; if the blood is prevented from flowing in it, the canal becomes obliterated by the adhesion of its parietes, and the vessel is converted into a ligamentous cord, such as that formed in the adult by the remains of the umbilical arteries and veins. This contractility, which, during life, is always in action, keeps the arteries, distended by the blood that fills them, of a smaller calibre than after death. In performing great operations, especially in the amputation of limbs, I have always found the arteries, whether filled with blood or empty, much smaller than I should have expected from their appearance in the dead body.

It happens, however, sometimes, that the quantity of blood sent to an organ increases, in consequence of some cause of irritation; the calibre of the arteries of the part then becomes remarkably enlarged. Thus, the arteries of the uterus, which are very small in its unimpregnated state, acquire, towards the end of pregnancy, a calibre equal to that of the radial artery; the small arteries which are sent to the mammæ are not in the same condition, as I have had an opportunity of ascertaining, in a woman who had been suckling a child for two months before her death—they retained their almost capillary minuteness; which would seem to prove, that the lymphatics are alone concerned in bringing to these glands the materials of their secretion. The mammary arteries are evidently enlarged in open cancer of the breast; in cancer of the penis, the blood-vessels likewise become enlarged; hence, in removing the penis for that affection, it is absolutely necessary to secure the arteries with ligatures,—a precaution which need not be

attended to in a case of gangrene. Gangrene is attended with this peculiarity, that the arteries of the mortified parts contract, so as to become obliterated, when their calibre is inconsiderable.

As the arteries are the canals which convey to all our organs the materials of growth and reparation, they are larger, in proportion, in children, in whom nutrition is more active, and their calibre is always proportionate to the natural or morbid development of organs: hence, the descending aorta and the iliac arteries are larger in women than in men; hence the right subclavian artery, which conveys blood to the larger and more powerful of the two upper extremities, because the more employed, is larger than the left subclavian. But the effect should not be mistaken for the cause, and it should not be imagined that the right upper extremity owes its superiority to the greater calibre of its artery. In the new-born child this vessel is not larger than the left subclavian; but the right arm being more frequently employed, the distribution of the fluids takes place more favourably, nutrition is carried on with more energy, it acquires more bulk and strength, and therefore the right subclavian artery conveys blood to it by a wider channel. If the left upper extremity were employed in the same manner, and if the right were kept in a state of inaction, the left subclavian would, no doubt, exceed the right. I am warranted by two facts in forming this conjecture. In dissecting the bodies of two men that were left-handed, I observed in the left subclavian arteries the same proportionate enlargement which is usually met with in the same vessels on the right side.

LVIII. *Of the pulse.*—As the arteries are always full during life, and as the blood flows along them with less velocity the greater their distance from the heart, the blood which the contractions of the left ventricle send into the aorta, meeting the column of blood already in that vessel, communicates to it the impulse which it has received; but, retarded in its direct progression by the resistance of that column, it acts against the parietes of the vessels, and removes them to a greater distance from their axis. This lateral action, which dilates the arteries, depends therefore, on the resistance of the parietes of these cavities, always filled with blood, to that which the heart sends into them. This dilatation, which is more considerable in the large arteries than in the smaller ones, manifests itself by a beat, known under the name of *pulse*. The experiments of Lamure would lead one to believe, that another cause of this phenomenon is a slight displacement of the arteries every time they dilate. These displacements are most easily observed at their curvatures, and where they adhere to surrounding parts by a loose and yielding cellular tissue.

The pulse is more frequent in women, in children, in persons of small stature, during the influence of the passions, and under violent bodily exercise, than in an adult man, of high stature, and of a calm physical and moral nature. At an early period of life, the pulse beats as often as a hundred and forty times in a minute. But as the child gets older, the motion of the circulation slackens, and at two years old the pulse beats only a hundred times in the same space of time. At the age of puperty, the beats of the pulse are about eighty in a minute; in manhood, seventy-five; and lastly, in old men of sixty the pulse is not above sixty.* It is slower in the inhabitants of cold than in those of warm climates.

Since the time of Galen, the pulse has furnished physicians with one of their principal sources of diagnosis. The force, the regularity, the equality of its pulsations, opposed to their weakness, inequality, irregularity, and

* The author has adduced the instance of an old man of eighty-seven years of age, in good health and spirits, whose pulse is only twenty-nine in a minute.—*J. C.*

intermittence, afford the means of judging of the nature and danger of a disease, of the power of nature in bringing about a cure, of the organ that is most affected, of the time or period of the complaint, &c. No one has been more successful than Bordeu in the consideration of the pulse under these different points of view. Its modifications indicative of the periods of diseases, establish, according to that celebrated physician, as may be seen in his *Recherches sur le pouls par rapport aux crises*, the pulse of *crudity*, of *irritation*, and of *concoction*. Certain general characters indicate whether the affection is situated above or below the diaphragm, hence the distinction of *superior* and *inferior pulse*. Lastly, peculiar characters denote the lesion of peculiar organs; which constitutes the nasal, guttural, pectoral, stomachic, hepatic, intestinal, renal, uterine, &c.

Besides these sensible beats, which constitute the phenomenon of the pulse in the arteries, there is an inward and obscure pulsatory motion, by which all the parts of the body are agitated every time that the ventricles of the heart contract. There is a kind of antagonism between the heart and the other organs; they yield to the impulse which it gives to the blood, dilate on receiving this fluid, and collapse when the effort of contraction is over. Every part vibrates, trembles, and palpitates, within the body; the motions of the heart shake the whole frame; and these quiverings, which may be observed externally, are most manifest when the circulation is carried on with rapidity and force. In some headachs, the internal carotid arteries pulsate with such violence, that not only the ear is sensible to the noise made by the column of blood striking against the curvature of the osseous canal, but the head is evidently moved and raised, as it were, at each pulsation. If you look at your hand or foot, when the upper or lower extremity is quiescent and pendulous, you will observe in it a slight motion, corresponding to the beats of the heart. This motion increases, and even makes the hand shake, when, from the influence of the passions, or from violent exercise, the circulation is accelerated; in every violent emotion, we feel within ourselves the effort by which the blood, at each beat of the pulse, penetrates into our organs, and fills every tissue. And it is in a great measure from this inward tact that we are conscious of existence;—a consciousness the more lively and distinct, as the effect of which we are speaking is more marked. It is likewise from observing this phenomenon, that several physiologists have been led to conceive the idea of a double motion, which dilates or condenses, which contracts or expands, alternately, all organs endowed with life: they have observed, that dilatation prevails in youth, in inflammation and erection,—conditions of which all parts are capable, according to their difference of structure.

LIX. *Uses of the aortal valves, &c.*—At the moment when the left ventricle contracts, to send the blood into the aorta, the sigmoid valves of that artery rise, and apply themselves to its parietes, without, however, closing the orifices of the coronary arteries, which lie above the loose edges of the valves; so that the blood is received into these vessels at the same time as into the others. When the contraction of the ventricle is over, the aorta acts on the blood which it contains, and would send it back into the ventricle, if the valves, by suddenly descending, did not present an insuperable obstacle to the return of blood, and did not yield a point of resistance to the action of the whole arterial system; only the small quantity of blood below the valves, at the moment of their descending, flows back towards the heart, and returns into the ventricle.

Though the rate at which the blood flows along the aorta has been estimated at only about eight inches in a second, a pulsation is felt in all the ar-

teries of a certain calibre, at the instant the ventricles are contracting. The reason why the pulsations of the heart appear to take place at the same time as those of the arteries is, that the columns of blood in these vessels receive an impulse from that which is issuing from the ventricles, and this concussion is felt in an instant of time, too short to be measured, such as that which is felt by the hand applied to the end of a piece of timber, struck at the other end with a hammer. The blood that fills the main trunk supplies to each of the branches which arise from it columns proportionate to their calibre. This division of the principal column is effected by a kind of projection at the mouth of each artery. These internal projections detach from the main stream the lesser ones, which flow the more readily into the branches, according as these arise from the trunk at a more acute angle, as the projection is more prominent, and the deviation of the fluid less considerable. If the branches are given off at an almost right angle, the orifices of the arteries scarcely project at all, and nothing but the effort of lateral pressure determines the flow of the blood into them.

The flow of the blood into the arteries which are distributed to muscles, is not interrupted when these muscles contract; for, whenever arteries of a certain calibre penetrate into muscles, they are surrounded by a tendinous ring, which, during the contraction of the muscle, becomes enlarged, from the extension in every direction effected by the fibres which are attached to it around its circumference. The existence of this truly admirable conformation may be readily ascertained by observing the aorta in its passage through the crura of the diaphragm; the perforating arteries of the thigh, where they enter at the back part of the limb into the adductor muscles; and the popliteal, as it passes through the upper extremity of the soleus muscle.

LX. *Of the capillary vessels.*—The arteries, after dividing into branches, these branches into lesser ones, and these into progressively smaller ramifications, terminate in the tissue of our organs, by becoming continuous with the veins. The venous system arises, therefore, from the arterial system, the origins of the veins being merely the more minute extremities of the arteries, which, becoming *capillary* from the great number of divisions* they have undergone, bend in an opposite direction, and become altered in their structure.

These minute capillary arteries form, with the minute veins with which they are continuous, and with the lymphatics, wonderful meshes in the tissue of our organs.

Several physiologists consider the capillary blood-vessels as an intermediate system between the arteries and veins, in which the blood, entirely out of the influence of the action of the heart, flows slowly, with an oscillatory and sometimes retrograde motion, is no longer red, because its globules are strained, as it were, and, in a manner, lost in a colourless serum, which serves them as a vehicle.

It is, in fact, necessary that bodies should be of a certain bulk to reflect the rays of light at an angle sufficiently obtuse that the eye may discover their colour. We know that grains of sand reduced to a very fine dust appear colourless when examined separately, and are seen to possess colour only when in a state of aggregation: further, very thin laminæ of a horny substance appear transparent, though the part from which they have been detached be of a red or blue colour. But if several of these transparent laminæ be laid on one another, the red colour becomes darker, in proportion as a greater number are brought together.

* The arterial divisions which may be discerned by the aid of anatomy do not exceed eighteen or twenty; nevertheless, they divide still further, when they are become so minute as not to be discernible without the help of the most powerful microscope.

Let irritation, from whatever cause, determine the blood to flow into the serous capillary vessels in greater quantity, and with more force, these vessels will become apparent, the organs in whose structure they circulate will acquire a red colour, more or less deep; thus, the conjunctiva, the pleura, the peritonæum, the cartilages, the ligaments, &c. which naturally are whitish or transparent, become red when affected with inflammation, either from the increased impetus of the circulation, which forces and accumulates into the capillary vessels a greater number of red globules, or that the sensibility of these small vessels is impaired by inflammation, so that they admit globules which they formerly rejected.

Some capillary vessels transmit blood at all times, and uniformly exhibit a red colour: this is the case with the capillary vessels of the spleen, of the corpora cavernosa of the penis, of the bulb and corpus spongiosum of the urethea; the same applies to the capillaries of the muscles of the mucous membranes: there are, however, very few of those organs in which the whole portion of the capillary tube, between the termination of the artery and the origin of the vein, is filled with red blood. There is almost always a division in the tortuous line described by the capillary, and within this space the blood cannot be detected of its usual colour.*

The number of the capillary vessels, as well as that of the arteries, to which the former are as auxiliaries, is much more considerable in the secretory organs than in those in which life carries on only the process of nutrition. It is on that account that the bones, the tendons, the ligaments, the cartilages, contain so much smaller a quantity of blood than the mucous and serous membranes and the skin. The capillary vessels are, however, very numerous in the muscles, which owe that colour to the great quantity of blood they contain; but, as we shall point out when we come to speak of motion, this fluid appears to form an essential element in muscular contraction; it is, therefore, not to be wondered that these organs should have a greater number of capillary vessels sent to them, since these vessels do not supply them merely with molecules to carry on nutrition, and to repair the waste of the part, but impart to them the principle of their frequent contraction: the quantity of them is so considerable in all these parts, employed in the twofold offices of nutrition and secretion, that Ruysch penetrated with his injections the whole thickness of their substance, to such a degree, that the organs which he had prepared were only a wonderful and inextricable network of capillary vessels, extremely minute. On these anatomical preparations, made with an art hitherto unrivalled, Ruysch grounded his hypothesis relative to the intimate structure of the body, in which he imagined all was capillary tubes,—an hypothesis which has obtained the most favourable reception, and has reigned during more than a century in the schools. It is enough to reflect a moment on their uses, to conceive that the number of them must be really prodigious. As long as the blood is enclosed within the arteries, and flows under the control of the heart, it fulfils no purpose, either of nutrition or secretion. To make it subservient to these great functions, it must be diffused through the very tissue of the organs, by means of the capillary divisions; these little vessels exist, then, in every part where any organised molecules are found united, since the particle formed by their assemblage must, at least, find in the juices which they bring to it the materials of its reparation. Entering, in greater or less proportion, into the or-

* There is every reason for concluding that capillary vessels exist, which, running between some of the terminations of the arteries and the commencement of veins, admit only the serous portion of the blood when performing their healthy functions; but which may, in a state of inflammation, admit also the red particles of this fluid to flow along them.—*J. C.*

ganisation of all the tissues, the capillaries receive certain modifications from the organs of which they are an integral part; modifications which enable them to deposit the serous part of the blood on the surface of the serous membranes, admit the transudation of the fat into the cells of the cellular tissue, furnish the urine to the kidneys, and the liver with the materials of the bile: in a word, suffer to escape through the porosities with which their parietes are pierced, the principles which the blood has to furnish to every organ.

It is by these lateral porosities, and not by extremities open on all the surfaces, and in all the points of the organs, that the capillaries transpire, in some sort, the elements of nutrition and of the various secretions.* Mascagni was aware that Nature, skilful in deducing many effects from few causes, has not deviated, in the construction of the system of circulation, from the invariable laws of her ordinary simplicity; but the lateral pores of the capillaries,—which are sufficient for the explanation of all the phenomena ascribed to the exhaling mouths of the arteries, and to the pretended continuity of these vessels with the excretory ducts of the organs, &c.—are not openings like the pores common to all matter; each of them may be considered as an orifice, sensible, and especially contractile, of differing size, according to the state of the strength or of the vital powers. The size, then, of these capillary pores is subject to frequent variations; and this is the explanation given of the formation of scorbutic ecchymoses, of petechiæ, and of passive or relaxed hæmorrhages. In all these affections, contractility being really diminished, the pores of the capillaries enlarge, and suffer the red blood to transude through their relaxed mouths. This phenomenon takes place, not only under the skin, and on the various mucous surfaces; it is observed also in the very tissue of the organs. It is thus that I have often seen, on opening the bodies of those that had died of scurvy in its last stage, the muscles of the leg filled with blood. This sort of interior hæmorrhage converts the muscles into a kind of pulp, and the extravasated blood itself undergoes a beginning of decomposition. The bones themselves are liable to these scorbutic, bloody infiltrations. I had an opportunity of ascertaining this in the Hospital of St. Louis, at the same time that I learnt the difficulty of procuring a durable skeleton from such bodies. The greatest number die in a very advanced stage of the disease, and the bones dissolve in maceration, or rot in a very little time.

The capillary vessels, whether the blood flow through them red or colourless, are not a system of vessels distinct from that of the arteries and from that of the veins; they belong essentially to these two orders of vessels. Those which, ramifying in the tissue of the skin or of the serous membranes, suffer the serum of the blood to transude, are not more entitled to the name of *exhalant system*, which some authors have given them. To consider as distinct and insulated systems, separate parts of a system of organs, is to encumber science with a crowd of divisions, as false as they are useless.

LXI.—The sanguineous capillaries anastomose, and form, like the lymphatic capillaries, a net-work that envelopes all the organs. Their frequent communications do not allow obstructions to take place, and to produce inflammation, as Boerhaave thought, and as was long taught on the authority of that celebrated physician. Haller, Spallanzani, all the microscopic observers, have perceived threads of blood flowing in the capillaries, offering themselves at the various inosculations of these vessels, and have seen them flow back, when they were not admitted, to seek other easier entrances.

* See APPENDIX, Note S, for observations on the Functions of the Capillary System, and on Nutrition.

I will not heap up in this place superfluous arguments against the theory of the Leyden professor, rejected at its birth by the physicians of Montpelier, absolutely refuted, and now universally given up. Irritation alone keeps the blood in the inflamed part; for when death, which puts an end to all irritations, and relaxes all spasms, (*mors spasmos solvit.* Hipp.) when, I say, death comes on, all slight inflammations are dissipated; and whenever they have not been sufficiently intense to induce transudation of the blood through the parietes of the capillaries into the *areolæ* of the organic tissues, the blood flows back into the large vessels, and there is no trace of it left. It is thus that erysipelas of the skin disappears, that the pleura preserves its transparency, in individuals affected before death with sharp pains in the side. If to this we add our ignorance of the real organisation of the nervous system, of the conditions absolutely required of the brain and nerves for the maintenance of life, we shall cease to be surprised that the opening of bodies has taught us no more on the real seat of disease; and we shall confess with Morgagni, who, however, employed with great success this means of improving the art of healing, that there are numberless diseases, of which, after death, no trace is left, and for the fatal termination of which we are unable to account.

Contractility and sensibility exist in a much higher degree in the capillary and serous vessels than in the veins and arteries. Life must needs be more active in the former; for, the motion given to the blood by the contractions of the heart being exhausted, this fluid, no longer in the sphere of action of that organ, can circulate but from the influence of the action of the vessels themselves.

The termination of the arteries into veins is the only well-ascertained termination of those vessels; it may be seen, by the help of the microscope, in cold-blooded animals, in frogs and salamanders. In some fish we may, even with the naked eye, observe frequent and considerable inosculations between the arteries and veins. In man, however, and in other warm-blooded animals, these communications take place only at the extremities of the two systems of vessels. In this case the arteries terminate sometimes in capillary vessels, carrying serous fluid, such as the vessels of the sclerotic coat; these vessels, become small veins, whose calibre gradually increases, until they admit red globules in sufficient number to reflect that colour. At other times the artery and vein are continuous, without the intervention of that extremely minute subdivision: the red blood then passes readily and immediately from the artery into the vein.

It will be shewn, in speaking of secretion, that the continuation of the arteries into the excretory ducts of the conglomerate glands, and their termination in exhaling orifices, cannot be admitted; and that the presence of small pores in the sides of the minute arteries and veins would afford an explanation of the phenomena on which the belief of this termination of the arteries rests. There exists no parenchyma, no spongy tissue, between the extremities of the arteries and the origin of the veins, with, perhaps, the exception of the substance of the cavernous bodies of the penis and of the clitoris, of the bulb and spongy part of the urethra,* the retiform plexus which surrounds the orifice of the vagina, and perhaps also the tissue of the spleen; though the experiments of anatomists (Mascagni and Lobstein) seem to prove that in these organs the arteries and veins are immediately continuous.†

LXII. *Of the distribution and action of the veins.*‡—These vessels, whose function it is to carry back to the heart the blood which the arteries have sent to all the organs, are much more numerous than the arteries themselves. It

* See the chapter on the *Organs of Generation.*

† See APPENDIX, Note T.

‡ See APPENDIX, Note N.

is observed, in fact, that arteries of a middle size, as those of the leg and fore arm, have each two corresponding veins, whose calibre at least equals theirs, and that there is, besides, a set of superficial veins, lying between the skin which covers the limbs, and the aponeuroses which envelop the muscles: these have no corresponding arteries. The space which the venous blood occupies is, therefore, much greater than that taken up by the blood in the arteries. Hence, also, it is estimated, that of twenty-eight or thirty pounds of this fluid, making about a fifth part of the whole weight of the body in an adult man, nine parts are present in the veins, and only four in the arteries. In this calculation, one should consider as arterial the blood contained in the pulmonary veins and in the left cavities of the heart, while that which fills the cavities in the right side of the heart and the pulmonary artery, is truly venous, and has every character of such blood.

Although the veins generally accompany the arteries, and are united to them by a common sheath of cellular membrane, this disposition of parts is not without exceptions. The veins which bring back the blood from the liver, do not, in any respect, follow the course of the branches of the hepatic artery; the sinuses of the brain are very different in their arrangement from the cerebral arteries; the veins of the bones, which are particularly numerous, and of a much greater calibre than the arteries of the same parts, from the slow circulation of the blood along them, do not generally follow the direction of the arteries, and arise singly from the substance of the bone, with the exception of those in the middle canal, and which pass through the nutritious foramen of the bone. The veins are not only more numerous than the arteries, but they are likewise more capacious, and dilate more readily: this structure was necessary, on account of the slowness with which the blood circulates, and of the readiness with which it stagnates, when the slightest obstacle impedes its circulation.* The force which carries on the circulation of the blood along the arteries is so great, that Nature seems not to have availed herself of the mechanical advantages which might have facilitated its flow. On the other hand, the power which determines the progression of the venous blood is so feeble, that she has sedulously removed every obstacle which might have impeded its course. And as the relation of the minute to the larger branches, and of these to the trunk, is the same as in the arteries,—two branches uniting to form a vein of greater calibre than each separate vessel, but smaller than the two taken together,—the blood flows along a space which becomes narrower the nearer it approaches the heart; the rapidity of its course must, therefore, be progressively increased.

The veins are almost straight in their course; at least, they are much less tortuous than the arteries. The force which makes the blood flow along them is consequently not taken up in straightening these curves; the anastomoses are likewise more frequent; and, as the flow of the blood might have been intercepted in the deep-seated veins of the limbs, when the muscles, among which these vessels lie during contraction, compress them by their enlargement and induration, they communicate freely with the superficial veins, towards which the blood is carried, and flows the more readily, as they are not liable to be compressed. It is observed, and is to be ac-

* The arteries contain, at all times, nearly the same quantity of blood. The veins are always the seat of plethora, because the blood stagnates in them more readily; and this condition brings on inflammatory fever (consisting merely in an increased action of the vascular system, as is expressed by the term *angeiotenique*, applied to it by Professor Pinel), only when the venous congestion becoming excessive, the blood passes with difficulty from the arteries into the veins. The heart and the arteries then struggle, with considerable effort, to rid themselves of the fluid which oppresses them, &c.

counted for on the same principle, that the superficial veins are very large and distinct among the lower orders, who are employed in laborious occupations, requiring an almost continual exertion of their limbs. Lastly, the internal part of the veins, like that of the lymphatics, is furnished with valvular folds, formed by the duplicature of their epidermoid coat. These valves, which are seldom single, and almost always in pairs, are not found in the minute veins, nor in the great trunks, nor in the veins which bring back the blood from the viscera in the great cavities.

These valves in falling close completely the canal of the vessel, destroy the continuity of the column of blood returning to the heart, divide it into smaller columns, as numerous as the intervals between the valves, and the height of which is determined by the distance between these folds. So that the power which carries onward the venous blood, and which would be incapable of propelling the whole mass, acts advantageously on each of the small portions into which it is divided.

LXIII.—It has been thought that the principal cause which makes the blood flow into the veins, is the combined action of the heart and arteries; but the impulse from those organs is lost in the system of capillary vessels, and does not extend to the veins. The specific action of their own parietes, aided by auxiliary means, such as the motion of the neighbouring arteries, is sufficient to carry the blood on to the heart.*

These parietes, which are much thinner than those of the arteries, are contained, like theirs, in a sheath common to all the vessels. Three coats, likewise, enter into their structure; the middle, or fibrous coat, is not very distinct, and consists merely of a few longitudinal reddish fibres, which can be distinguished only in the larger veins near the heart. In some of the larger quadrupeds, as in the ox, these fibres form distinct fasciculi, and their muscularity is much more manifest.

The internal coat, which is more extensible than that of the arteries, and equally thin, adheres more closely to the other coats. The cellular coat, which connects it to the middle one, is less abundant; hence phosphate of lime is seldom deposited into it, as happens to the arteries, which frequently become ossified as we advance in years. This internal coat is merely a continuation of that which lines the cavities of the heart; and as the origin of the inner coat of the arteries is the same, there exists a non-interrupted continuity in the membrane which lines all the canals of the circulation. The inner coat forms the only essential part of the venous system; it alone constitutes the veins within the bones, the sinuses of the dura mater, the hepatic veins, in a word, all the veins which are so firmly attached externally to the neighbouring parts, that the blood flows along them as along inert tubes, their parietes being almost completely incapable of contracting.

The veins in their passage through muscles, are, like the arteries, guarded by aponeurotic rings, than which none is more remarkable than that belonging to the aperture in the diaphragm, which transmits the ascending cava from the abdomen into the thorax. This vessel is, therefore, not compressed by the contraction of that muscle in inspiration.

LXIV.—As the inferior cava passes through the lower edge of the liver, whether along a deep fissure, or in a real canal in the parenchymatous substance of that viscus, the course of the blood must be impeded, when, from congestion of the parenchyma, the vessel is, in some sort, strangulated.

Obstruction of the liver, which is of such frequent occurrence, would have

* It would perhaps be more just to assign the cause of the flow of blood in the veins to the *vis à tergo*, assisted by the action of their own parietes, and by the active dilatation of the heart. See APPENDIX, Note T.—*J. C.*

been attended with fatal consequences, by preventing the return of the blood from the inferior parts, along the ascending cava, if this great venous trunk did not keep up, by means of the vena azygos, an open and free communication with the descending or superior cava. The use of this anastomosis of the two great veins, is evidently to facilitate the passage of the blood from the one of these vessels into the other, when either, especially the lower, does not readily evacuate its contents into the right auricle. On this account, the vena azygos is capable of considerable dilatation, and is entirely without valves. In the body of a man opened this day in my presence, and whose liver was twice as large as in health, I observed that the vena azygos, which was distended with blood, was of the size of the little finger: the terminations downwards of this vessel, in the right renal vein, and above in the superior cava, were most distinct; and by compressing it from above downward, or from below upward, the blood flowed into the one or other of these vessels.

As the causes which determine the circulation of the venous blood communicate to it an impulse which is far from rapid, and as this fluid meets with only trifling obstacles, and such as are easily overcome, the pressure against the parietes of the veins is very inconsiderable; and these vessels do not pulsate as the arteries. There is observed, however, near the heart an undulatory motion, which the blood communicates to the parietes of the vessels. These kinds of alternate pulsations depend on the rapidity with which the blood, whose course is progressively accelerated, flows towards the heart, and on the reflux of the blood during the contraction of the right auricle. The contraction of this cavity forces back the blood into the veins which open into it; this retrograde course is manifest in the superior cava, and is the more readily occasioned, as the orifice of this vein is not furnished with any valve that might prevent it. It does not, however, extend very far towards the brain, the blood having to ascend against its own weight, and the jugulars admitting of considerable dilatation. This regurgitation is still more marked in the inferior cava, the orifice of which is but imperfectly closed by the valve of Eustachius; it is felt in the abdominal veins, and extends even to the external iliacs, according to the testimony of Haller.

LXV.—The orifice of the great coronary vein being exactly covered over by its valve, the blood does not return into the tissue of the heart, which, being a contractile organ, would have had its irritability impaired by the presence of venous blood. It is of consequence to observe, that this reflux never extends to the veins which bring back the blood from the muscles, and that it is never felt in the veins of the limbs which are furnished internally with valvular folds. The case is very different between our organs of motion and these secretory glands: towards these latter the blood is required to be sent back, so as to be the longer exposed to their action; whereas venous blood diminishes and even destroys muscular irritability, and is truly oppressive to the organs of motion, as may be ascertained by injecting some in the arteries of a living animal, or else by tying the veins, so as to prevent its return, or by observing what happens when the course of the blood is interrupted, either by applying firm ligatures round the limbs, or by wearing confined clothes.

I am satisfied, that it was from observing the oscillatory undulations of the venous blood in the great vessels, that the ancients were led to the opinions they entertained on the course of the blood, which they compared to the Euripus, whose waves were represented by the poets as uncertain in their course, and in currents running in contrary directions.

The internal veins in which this reflux is observed shew this motion of the blood most distinctly of any; their sides, which are thin and semi-transparent, not being, as in other parts, surrounded by an adipose cellular tissue. To

give a complete notion of the doctrine of the ancients on the subject of the circulation, it will merely be necessary to add to the above idea the opinion which they entertained, that the chyle taken up by the meseraic veins was carried to the liver, in which its sanguification was effected ; and lastly, that the arteries were filled with vital spirit, and contained only a few drops of blood, which passed through small holes, that Galen says, perforate the septum of the ventricles.

The blood, however, continually urged on by the columns which follow each other in succession, by the action of the veins whose parietes become gradually stronger, and by the compression which these vessels experience from the viscera during the motions of respiration, reaches the heart, and enters the auricles with the greater facility, as the orifices of the cavæ not being directly opposed to each other, the columns of blood which they convey do not meet, and do not oppose each other.

LXVI. *Of the general or systemic circulation.*—The blood continually carried to all parts of the body by the arteries, returns, therefore, to the heart, by a motion which can never be interrupted without considerable danger of life. We know that the circulation is thus effected, from the direction of the valves of the heart, of the arteries and veins, by what happens when these vessels are opened, compressed, or tied, or when a fluid is injected into them. When an artery is wounded, the blood comes from the part of the vessel nearest the heart ; it comes, on the contrary, from towards the extremities, if it is a vein that has been opened. By compressing or tying an artery, the course of the blood is suspended below the ligature, and the vessel swells above. The veins, on the contrary, when tied or compressed, dilate below. Lastly, when an acid fluid is injected into a vein, the blood is seen to coagulate in the direction of the heart. By the help of the microscope, we may see in the semi-transparent vessels of frogs and other cold-blooded animals, the blood flowing from the heart into the arteries, and from these into the veins, which return it to the heart. It was on the strength of these convincing proofs, that William Harvey established, towards the middle of the sixteenth century, the theory of the circulation of the blood. Its mechanism had been rather guessed at, than understood, by several authors ; Servetus and Cesalpine appear to have been acquainted with it ; but no one has more clearly explained it than the English physiologist, who is justly considered the author of that immortal discovery.

LXVII. The theory of Harvey, such as it is laid down in his work, entitled, *De sanguinis circuitu exercitationes anatomicæ*, does not appear to me entirely admissible. He considers the heart as the only agent which sets the blood in motion, and does not take into account the action of the veins and arteries, which he considers as completely inert tubes ; while every thing tends to prove that the arteries and veins assist the motion of the blood,* by an action peculiar to themselves. He admits, that the blood flows in every part of the circulatory system with an uniform degree of speed ; an opinion so manifestly contradicted by reasoning and experience, which prove that the velocity of its course diminishes, the greater its distance from the heart, from the influence of a great number of circumstances, which it would be useless to repeat (LVII). This doctrine has yet, however, several abettors ; and among the moderns, Spallanzani has endeavoured to support it, by a number of experiments so contradictory, that one is surprised that so judicious a physiologist should have collected them to establish a theory completely refuted by several of them. Nothing, for example, contradicts it more fully, than the continuation of the flow of the blood, in

* See Appendix, Notes A, B, S, T.

the vessels of frogs and salamanders, after the heart of these reptiles has been torn out: there are, besides, animals which, not possessed of that central organ, have, nevertheless, vessels along which the blood flows, and which contract and dilate by alternate motions.

If the mere force of the heart propelled the blood to every part, the course of this fluid ought, at intervals, to be suspended: its circulation, at least, ought to be slackened when the ventricles cease to contract; but as the contraction of the arteries corresponds to the relaxation of the ventricles, these two powers, whose action alternates, are continually employed in propelling the blood along its innumerable channels.

Besides the general circulation, of which the laws and phenomena have just been mentioned, each part may be said to have its peculiar mode of circulation, more or less rapid, according to the arrangement and structure of its vessels. Each of these individual circulations forms a part of the machinery included in the great circle of the general circulation, and in which the course of the blood takes place in a different manner, may be accelerated or retarded, without affecting the general circulation. Thus, the circulation in the brain is modified from that of the lungs; and this latter, from the circulation of the abdominal viscera, the venous blood of which, destined to furnish the materials of the bile, flows much more slowly than that of other parts.

These modifications, affecting the velocity of the circulatory motion of the blood, account for the difference of its qualities in different organs: all these differences form a part of the plan of nature, and it is not difficult to understand their utility.

LXVIII. *Of the pulmonary or lesser circulation.*—In what has been said of the circulation, no separate mention has been made of the course of the blood through the lungs, called by authors the lesser or pulmonary circulation. The vascular system of the lungs, with the addition even of the cavities of the heart which belong to it, does not represent a complete circle; it is only a segment, or rather an arch, of the great circle of general circulation.

The blood, in going along that great circle, meets with the organs, situated like so many points of intersection in the course of the vessel, which form that circle.

To render still more simple the idea which is to be entertained on the subject, one may reduce these intersections to two principal ones; the one corresponding to the lungs, the other to the rest of the body; the veins, the right cavities of the heart, and the pulmonary artery with its divisions, forming one half of the circle; the pulmonary veins, the left cavities of the heart, the aorta with all its branches, representing the other half. The capillary vessels of the lungs form one of the points of intersection, and the capillaries of all the other organs represent the other point of intersection, by uniting together the arteries and veins of the whole body, in the same manner as those of the lungs establish a communication between the veins and arteries of these organs.

This division of the system of circulation into two parts, in one of which there circulates a dark venous blood, while the other contains red or arterial blood, is at once more simple and more accurate. As was already stated, in the history of the circulation, its organs are, in an especial manner, destined to the mechanical act of conveying the fluids: the changes, the alterations which the blood undergoes in passing through the organs, are effected only at the moment when, in penetrating into their tissue, it passes into the capillary vessels which are distributed into them. The columns of blood are

then sufficiently minute to be operated upon by the vital action ; till then, the columns of blood are too large, and resist, by their bulk, if one may so speak, any decomposition. It is, therefore, in the capillary vessels that the blood undergoes its essential changes, and from them it deposits its nutritious elements ; and to understand how the nutritious lymph, which is carried by the thoracic duct into the left subclavian vein, experiences, in its course along the sanguiferous system, the changes which are to assimilate it to our own substance, it is necessary to follow it, along the venous blood with which it unites, into the heart, through the right half of which it passes in its way to the lungs, there to combine with the atmospherical air, from which we are perpetually deriving another aliment indispensable to life ; then, to examine how, when modified and conveyed with the red blood from the lungs to the whole body, it serves to the secretions, and supplies nourishment to the different structures of the frame.

In considering, in this manner, the circulation of the blood, with a reference to the changes which it undergoes in the organs through which it passes in describing that circle, we shall find that this fluid, already combined with the lymph and chyle, parts, in the lungs, with some of its principles, at the same time that it becomes impregnated with the vital portion of the atmosphere, which suddenly changes its colour and other qualities. The blood will then be seen to flow into all the parts which it stimulates, to keep up their energy, to awaken their action, and furnish them the materials of the fluids which they secrete, or the molecules by which they grow or are repaired ; so that, in supplying thus the different organs, the blood loses all the qualities which it had acquired by the union of the chyle and of the vital air, parts with the principles to which it owed its colour, and again becomes dark, to be repaired anew by combining with the lymph, and by the absorption of the vital part of the atmospheric air :* this constitutes the principal phenomenon of the function which will be considered in our next chapter.

CHAPTER IV.

OF RESPIRATION

LXIX. The Purposes of this Function.—LXX. Of the Atmosphere.—LXXI. The Mechanism of the Respiratory Organs.—LXXII. Actions of the Respiratory Muscles.—LXXIII. Of Inspiration and Expiration.—LXXIV. State of the Lungs during Inspiration.—LXXV. Of the Pulmonary Vessels.—LXXVI. Changes induced on the Blood and in the Air by Respiration.—LXXVII. Of the nervous Influence in the function of Respiration.—LXXVIII. and LXXIX. Of Animal Heat.—LXXX. and LXXXI. Of the Causes enabling the Body to resist Increase or Diminution of Temperature.—LXXXII. Source of Animal Heat.—LXXXIII. The Pulmonary Circulation, and Changes induced upon the Chyle received into the Venous Blood.—LXXXIV. Of Pulmonary Exhalation.—LXXXV. Of Asphyxia.—LXXXVI. Of Sighing, Sobbing, Yawning, Sneezing, Coughing, Hiccup, Laughing, &c.—LXXXVII. Of the Cutaneous Perspiration.

LXIX.—Of the different changes which the blood undergoes in the different organs, none are more essential or more remarkable than those it receives from the air which during respiration is alternately received into the lungs and expelled from them. The blood which the veins convey to the heart, and which the right ventricle transmits to the lungs, is of a dark colour, and heavy ; its temperature is only thirty degrees (Reaumur) ; if laid by, it coagulates slowly, and there is separated from it a considerable quantity of serum.

* See the Note on Respiration, in the Appendix, for a different opinion.

The blood which is brought by the pulmonary veins to the left side of the heart, and which is conveyed to all parts of the body by means of the arteries, is, on the contrary, of a florid red colour ; it is spumous, lighter, and warmer by two degrees. It likewise coagulates more readily, and contains a smaller quantity of serum. All these differences, which are so easily distinguished, depend on the changes which it has undergone, by being in contact with the atmospherical air.

LXX. *Of the atmosphere.*—The mass of air which surrounds the globe, and to which we give the name of atmosphere, bears on all bodies with a pressure proportioned to their surface. That of man* bears a weight of air amounting to about thirty-six thousand pounds. Moreover, one of its constituent principles is absolutely necessary to the keeping up of life, of which it is a principal agent.

The variations in the weight of the atmosphere have, in general, but little influence on the exercise of the functions ; nevertheless, when, by ascending the tops of very high mountains, man rises several thousand fathoms above the level of the sea, the remarkable diminution of the weight of the air produces a very sensible effect. Respiration becomes laborious and panting, the pulse is quickened, and there is felt an universal uneasiness joined to excessive weakness, and hæmorrhages come on : these symptoms are occasioned both by the diminished pressure of the air and by the smaller quantity of oxygen contained in a rarer atmosphere.—(Saussure, *Voyage au Mont-Blanc.*)

The human body resists, without any effort, the atmospherical pressure, because it is applied at all times, and in every direction.† But if a part of its surface ceases for a moment to be under its influence, it swells, the fluids are determined to it in considerable quantity, the integuments become excessively distended, so as to be in danger of bursting ; such are the phenomena which attend the application of cupping glasses.

The pressure of the air on the surface of the globe is necessary to the existence of bodies in the condition in which we see them. Several very volatile fluids, as alcohol and ether, would become gaseous under a less pressure of the atmosphere ; water would boil under eighty degrees of temperature (Reaumur's scale) ; solid bodies themselves might become fluid. In a word, a considerable diminution in the weight of the atmosphere would have absolutely the same effect as raising its temperature to a very great height, which, changing the face of the universe, would convert all liquids into elastic fluids, and would, doubtless, melt all solid bodies.

The variations in the weight of the atmosphere, distinguishable by the barometer, are of very little importance to the physiologist, and, I might even add, to the physician, notwithstanding the minute attention with which some writers note the state of the barometer, of the thermometer and hygrometer, and of the electrical state of the atmosphere, in giving an account of a disease or of an experiment, on which the above circumstances have no apparent or certain influence. The atmosphere, like every other fluid, has a perpetual tendency to a state of equilibrium ; hence the rush of air into the lungs, or into other situations, in which its quantity is diminished by the combinations which it forms, or by the effects of heat, which renders it lighter by rarefaction the same principle explains the formation of the trade and other winds.

* The surface of the body is estimated at fifteen or sixteen square feet, in a man of middle size.

† The pressure of the atmosphere is even necessary to the due performance of some of our functions, as particularly respiration and venous circulation, to which latter, according to the experiments of Dr. Curson and Dr. Barry, it appears to contribute. See on this subject the Notes on Respiration, in the APPENDIX.—*J. C.*

The atmospherical air combines with water and dissolves it, as the latter dissolves saline substances. In this consists the process of evaporation. The air becomes saturated with water, in the same manner as water becomes saturated with salt, to such a degree as to be incapable of holding a greater quantity in solution. As its temperature rises, its solvent power increases, and the latter diminishes as it grows cold; variations of temperature produce the same effect on solutions of salts in liquids. The formation of all the aqueous meteors depends on the different conditions of the solvent powers of the atmosphere; when considerable, the atmosphere is warm and dry, and the air serene; clouds form when it is saturated; dews, fogs, and rain, are the consequence of a diminution of its solvent power, as snow and hail of a degree of cold which precipitates the fluid The different degrees of dryness or moisture, marked by the hygrometer, only sensibly affect the human body when it has been exposed for a considerable time to its influence.

Chemically considered, the atmospherical air, which was long regarded as a simple body, is composed of about ·21 of oxygen, ·79 of azote, by measure, and of ·01 or ·02 of carbonic acid. The carbonic acid is the more abundant as the air is less pure. This part of natural philosophy, which is called eudiometry, or the measurement of the purity of the air, is far from accomplishing what its name indicates, and has disappointed the hopes which had been entertained on the subject. Eudiometrical instruments can inform us only of the proportion of oxygen contained in the atmosphere; now, its salubrity, its fitness for respiration, is not in proportion to the quantity of oxygen. The volatilised remains of putrid animal or vegetable substances, and various mephitic gases, combine with it and affect its purity. In the comparative analysis of air procured on the Alps and in the marshes of Lombardy, there was found in each the same quantity of oxygen; and yet, those who breathe the former enjoy robust health, while the inhabitants of the marshy plains of Lombardy are carried off by epidemic diseases, are pale, emaciated, and habitually lead a languid existence.

Though at least ·20 parts of oxygen are necessary to render the air fit for respiration, the proportion may be diminished to seven or eight parts in the hundred; but in such cases the breathing is laborious, panting, and attended with a sense of suffocation; in short, asphyxia comes on even while the air still contains a certain quantity of oxygen, of which the lungs cannot entirely deprive it. Whenever a number of persons are collected in a confined place, in which the air cannot be easily renewed, the quantity of oxygen diminishes rapidly, while that of carbonic acid increases. The latter, in consequence of its specific gravity, sinks to the lowest part, and strikes with death every living being which it envelopes. When two lighted candles of different lengths are placed under the same bell, the shorter candle goes out first, because the carbonic acid formed during combustion sinks to the most depending part. For the same reason, the pit is the most unhealthy part of a playhouse, when a great number of people, after remaining in it for several hours, have deprived the air of a considerable portion of its oxygen.

Persons collected together and enclosed in a small space, injure each other, not only by depriving the atmosphere of its respirable element, but particularly by altering its composition, by the combination of all the substances exhaled from their bodies. These volatilised animal emanations become putrid while in the atmosphere, and conveyed to the lungs during respiration, become the germ of the most fatal diseases It is in this manner that the gaol and hospital fever, so fatal to almost all whom it attacks, arises and spreads. A dry and temperate air, containing ·21 of oxygen and ·79 of azote, and free of other gases or other volatilised substances, is the fittest for respiration. In

certain cases of disease, however, this function is most freely performed in a less pure air. Thus, patients labouring under pulmonary consumption, prefer the thick and damp air of low situations to the sharp and dry air of mountains; nervous women prefer that in which horn, feathers, or other animal substances are burning. An atmosphere highly electrical, at the approach of a storm, renders respiration very laborious, in some cases of asthma. In short, the qualities of the air must be suited to the condition of the vital power in the lungs, as those of the food to the sensibility of the stomach.

Being obliged, on this subject, to content myself with the ungracious office of compiler, I hasten to bring this article to a close, and to refer the reader for a fuller account of the air, considered in its physical and chemical relations, to the works of MM. Fourcroy, Haüy, Brisson, Thenard, &c.; and to that of M. Guyton Morveau, on the method of purifying the air, when from different combinations it is become unfit for respiration.

LXXI. *The mechanism of the respiratory organs.*—In man, and in all warm-blooded animals, with a heart containing two auricles and two ventricles, the blood which has been conveyed to all the organs by the arteries, and which has been brought back by the veins to the heart, cannot return to it without having previously passed through the lungs, which are viscera destined to the transmission of air, of a spungy texture, and through which the blood must, of necessity, circulate, to get from the right to the left cavities of the heart. This course of the blood constitutes the pulmonary, or lesser circulation: it does not exist in some cold-blooded animals. In reptiles, for instance, the heart has but one auricle and one ventricle; the pulmonary artery in them arises from the aorta, and conveys but a small proportion of the blood; hence, the habitual temperature of these animals is much lower than that of man. For the same reason, too, there exists so small a difference between their venous and arterial blood; the quantity of fluid vivified by exposure to the air in the pulmonary tissue being too small to effect, by its union with the general mass, a material change on its qualities.

Mayow has given the most accurate notion of the respiratory organ by comparing it to a pair of bellows, containing an empty bladder, the neck of which, by being adapted to that of the bellows, should admit air on drawing asunder its sides. The air, in fact, enters the lungs only when the chest dilates and enlarges, by the separation of its parietes. The agents of respiration are, therefore, the muscles which move the parietes of the chest: these parietes are formed of osseous and soft parts, in such a manner as to possess a solidity proportioned to the importance of the organs which the chest contains, besides a capacity of motion required to carry on the functions intrusted to them.*

To carry on respiration, which may be defined the alternate ingress of air into the lungs and its egress from those organs, it is necessary that the dimensions of the chest should be enlarged (this active dilatation of the cavity of the chest is called inspiration), and that it should contract to expel the air which it had received during the first process. This second action is called expiration; it is always of shorter duration than the former, its agents are more mechanical, and the muscles have much less influence upon it.

The parietes of the chest are formed, at the back part, by the vertebral column, at the fore part by the sternum, and on the sides by the ribs, which are osseo-cartilaginous arches, situated obliquely between the vertebral column, which is fixed, and becomes the point of support of their motions, and the sternum which is somewhat movable—the spaces between the ribs are filled by muscular planes of inconsiderable thickness, consisting of the inter-

* See APPENDIX, Note U, for remarks on the Mechanism of the Respiratory Organs

nal and external intercostal muscles, the fibres of which lie in opposite directions. Besides, several muscles cover the outer part of the thorax, and pass from the ribs to the neighbouring bones; as the subclavian muscles, the great and lesser pectorals, the serrati, the latissimi dorsi, the scaleni, the longissimi dorsi, the sacro-lumbales, and the serrati minores, posteriores, and inferiores. But of all the muscles which form the anterior, posterior, and lateral parietes of the chest, the most important is the diaphragm, a fleshy and tendinous partition, lying horizontally between the chest and the abdomen, which it divides from each other; it is attached to the cartilages of the false ribs, and to the lumbar vertebræ, and has three openings to transmit the œsophagus and the vessels which pass from the abdomen to the chest, or from the latter into the abdomen.

In health, the chest dilates only by the descent of the diaphragm. The curved fibres of that muscle, straightened in contraction, descend towards the abdomen, and compress the viscera. The descent of the viscera thrusts forward the anterior parietes of that cavity, and these recede, when, on expiration taking place after inspiration, the diaphragm, now relaxed, rises, pressed upward by the abdominal viscera, compressed themselves by the large muscles of the abdomen. But when it is necessary to take into the chest a great quantity of air, it is not sufficient that it should be enlarged merely by the descent of the diaphragm—it is required besides, that its dimensions should be increased in every direction. The intercostal muscles then contract, and tend to bring together the ribs between which they are situated. The intercostal spaces, however, become wider, especially at their anterior part; for, whenever lines falling obliquely on a vertical line change their direction, approaching to a right angle, the intermediate spaces receive the greater increase, as the lines, more oblique at first, become at last more nearly horizontal. Besides, as the ribs are curved in the course of their length in two directions, and both in the direction of their faces and edgewise, the convexity of the first curvature is outwards, and the ribs recede to a distance from the axis of the chest, whose cavity is enlarged transversely; while the second curvature (in the direction of their edge) being increased by a real twisting of these bones, and which reaches to the cartilaginous parts, the sternum is heaved forward and upward, so that the posterior extremity of the ribs is removed from their sternal end. But as the ribs are not all equally movable,—as the first is almost always invariably fixed, and as the others are movable in proportion to their length,—the sternum is tilted in such a way that the lowermost extremity is thrust forward. The diameter of the chest from the fore to the back part increases, therefore, as well as the transverse diameter. This increase of dimensions has been estimated at two inches to each of these diameters; the dimensions of the vertical diameter, which are regulated by the depression of the diaphragm, are much greater.

LXXII. *Action of the respiratory muscles.*—Professor Sabatier, in his memoir on the motion of the ribs, and on the action of the intercostal muscles, maintains, that during the action of inspiration, the upper ribs alone rise, that the lower ribs descend and slightly close on the chest, while the middle ribs project outwardly; and that in expiration, the former set of ribs descend, that the latter start a little outwardly, and that the middle set encroach on the cavity of the chest. The learned professor adds, that the cartilaginous articulating surfaces, by which the ribs are connected to the transverse processes of the vertebræ, appear to him to favour these different motions, as the direction of the articulations of the upper ribs is upward, and that of the lower downward; but, on considering the subject with attention, it will be seen, that the surfaces by which the transverse processes of the vertebræ are articulated to the

tuberosities of the ribs, are turned directly forward in the greatest number, while some of the lower ribs are, at the same time, directed slightly upward. If we examine the action of the bones of the chest during inspiration, in a very thin person,—for example, in phthisical patients, whose bones are covered with little else than skin,—we shall find, that all the ribs rise, and are carried somewhat outwardly. It is not easy to conceive how the intercostal muscles, which Professor Sabatier considers as the agents of respiration, should elevate the upper ribs and depress the lower. The diaphragm, whose circumference is inserted in the latter, might, by its contraction, produce this effect; but as the intercostals have their fixed point of action in the upper ribs, they oppose and neutralise this effort, and all the ribs are elevated at once. If this were not the case, the ribs ought to be depressed whenever the intercostals contract, since the lowermost, fixed by the diaphragm, would become the fixed point on which all the others should move.

As the fibres of the external and internal intercostal muscles are in direct opposition to each other,—those of the former set of muscles having an oblique direction, from above downward, and from behind forward, and crossing the fibres of the other set, whose obliquity is in a different direction,—several physiologists have thought that these muscles were opposed to each other; that the internal intercostal muscles brought together the ribs after they had been separated by the external intercostals, the one set being muscles of expiration, while the other set contracted during inspiration.

It is well known with what pertinacity Hamberger, in other respects a physiologist of considerable merit, defended this erroneous opinion in his dispute with Haller: it is now, however, ascertained, that all the intercostal muscles concur in dilating the chest, and that they ought to be ranked among the agents of inspiration, because the unequal capacity of motion in the ribs prevents the internal intercostals, the lower insertion of which is nearer to the articulation of these bones to the vertebræ, from depressing the upper ribs. Of the very conclusive experiments by which Haller undertook to refute the arguments of his adversary, I shall relate only that which is performed by stripping the parietes of the chest in a living animal of all the muscles which cover it, and by removing, in different parts of the thorax, some of the external intercostal muscles. The internal intercostals are then seen to contract during inspiration, together with the remaining external intercostals. These muscles, therefore, have a common action, and are not in opposition to each other. The same experiment serves to prove the increased dimensions of the space between the ribs. On holding one's finger between two of the ribs, it feels less confined, when, during inspiration, these bones rise and thrust forward the sternum.

This question being at rest, although in the pursuit of science one should inquire how things are effected, and not wherefore they come to pass, we feel naturally desirous to know what purpose is answered by the different direction of the fibres of the two sets of intercostal muscles; and with what view Nature has departed from her wonted simplicity, in giving to their fibres opposite directions. In answer to this I may observe, that the action of powers applied obliquely to a lever being decomposed in consequence of that obliquity, a part of the action of the external intercostals would tend to draw the ribs towards the vertebral column, which could not happen without forcing back the sternum, if the internal intercostals did not tend to bring forward the ribs at the same time that they elevate them; so that these two muscular planes, united in their action of raising the ribs, antagonise and reciprocally neutralise each other, in the effort by which they tend to draw them in different directions.

To this advantage of mutually correcting the effects that would result from their respective obliquity, may be added the benefit arising from a texture capable of a greater resistance: it is clearly obvious, that a tissue whose threads cross each other, is firmer than one in which all the threads, merely in juxta-position, or united by means of another substance, should all lie in the same direction. Hence Nature has adopted this arrangement in the formation of the muscular planes constituting the anterior and lateral parietes of the abdomen, without which the abdominal viscera would frequently have formed herniary tumours, by separating the fibres and getting engaged between them. In this respect we may compare the tissue of the abdominal parietes,—in which the fibres of the external and internal oblique muscles, which cross each other, are themselves crossed by the fibres of the transversales,—to the tissue of those stuffs whose threads cross each other, or rather to wicker-work, to which basket-makers give so much strength by interweaving the osier in a variety of directions.

LXXIII. *Of inspiration and expiration.*—When from any cause respiration becomes difficult, and the diaphragm is prevented from descending towards the abdomen, or the motion of inspiration in any way impeded, the intercostals are not alone employed in dilating the chest, but are assisted by several other auxiliary muscles; the scaleni, the subclavii, the pectorals, the serrati magni, and the latissimi dorsi, by contracting, elevate the ribs, and increase, in more directions than one, the diameter of the chest. The fixed point of these muscles then becomes their movable point, the cervical column, the clavicle, the scapula, and the humerus, being kept fixed by other powers, which it is unnecessary to enumerate. Whoever witnesses a fit of convulsive asthma, or of a suffocating cough, will readily understand the importance and action of these auxiliary muscles.

Inspiration is truly a state of action, an effort of contractile organs, which must cease when these are relaxed. The expiration which follows is passive, and assisted by very few muscles, depending chiefly on the re-action of the elastic parts which enter into the structure of the parietes of the chest. We have seen that the cartilages of the ribs are pretty considerably twisted, so as to carry outward and downward their upper edge: when the cause which occasions this twisting ceases to act, these parts return to their natural condition, and bring back the sternum towards the vertebral column, towards which the ribs descend from their weight. The diaphragm is forced towards the chest by the abdominal viscera, which are compressed by the broad muscles of the abdomen.

In every effort of expiration, as in cough and vomiting, these muscles re-act, not merely by their own elasticity, but they besides contract and tend to approach towards the vertebral column, by pressing upwards the abdominal viscera towards the chest. The triangularis sterni, the subcostales, and the serratus inferior pesticus, may likewise be ranked among the agents of expiration; but they appear to be seldom employed, and to be too slender and weak to contribute much to the contraction of the chest.

LXXIV. *State of the lungs during inspiration.*—When the chest enlarges, the lungs dilate and follow its parietes as these recede from each other. These two viscera, soft, spongy, and of less specific gravity than water, covered by the pleura, which is reflected over them, are always in contact with the portion of that membrane which lines the cavity of the thorax; no air is interposed between their surfaces (which are habitually moistened by a serous fluid exuding from the pleura) and that membrane, as may be seen by opening under water the body of a living animal, when no air will be seen to escape. As the lungs dilate their vessels expand, and the blood cir-

culates through them more freely : the air contained in the innumerable cells of their tissue becomes rarified, in proportion as the space in which it is contained is enlarged. Besides, the warmth communicated to it by the surrounding parts, enables it, in a very imperfect manner, to resist the pressure of the atmosphere, rushing through the nostrils and mouth into the lungs, by the opening in the larynx, which is always previous except during deglutition.

LXXV. *Of the pulmonary vessels.*—The pulmonary tissue into which the air is thus drawn every time the capacity of the chest is increased, does not consist merely of air-vessels, which are but branches, of different sizes, of the two principal divisions of the trachea, but is formed, likewise, by the lobular tissue into which these canals deposit the air ; it contains, also, a great quantity of lymphatics and blood-vessels, of glands and nerves. Cellular tissue unites together all these parts, and forms them into two masses, covered over by the pleura, and of nearly the same bulk ;* suspended in the chest from the bronchia and trachea, and every where in contact with the parietes of the cavities of the chest, except towards their root, at which they receive all their nerves and vessels.

The pulmonary artery arises from the base of the right ventricle, and divides into two arteries, one to each lung. On reaching the substance of the lungs, these arteries divide into as many branches as there are principal lobes. From these branches there arise others, which again subdivide into lesser ones, until they become capillary, and continuous with the radicles of the pulmonary veins.

These vessels, formed from the extremities of the artery, unite into trunks, which progressively enlarging, emerge from the lungs, and open, four in number, into the left auricle. Besides these large vessels, by means of which the cavities in both sides of the heart communicate together, the lungs receive from the aorta two or three arteries called bronchial arteries : these penetrate into their tissue, where they follow the direction of the other vessels, and terminate in the bronchial veins, which open in the superior cava, not far from its termination into the right auricle. These bronchial vessels are sufficient for the nourishment of the pulmonary organ, which, in reality, is not near so bulky as it appears, as may be ascertained by examining the lungs after all the air has been extracted from them, by means of an air-pump applied to the trachea.

Physiologists, for the most part, consider the bronchial arteries as the nutritious vessels of the lungs. They assert, that as the blood which flows along the branches of the pulmonary artery resembles venous blood, it is unfit for the nutrition of the lungs, and that it was necessary that these organs should be supplied by arteries arising from the aorta, and containing blood analogous to that which is sent to every part of the body. But though it be admitted that this venous blood, brought from every part of the body and sent into the lungs by their principal artery, may not be fit to maintain the organ in its natural economy, this blood is fit for that use, when, after being made hot, spumous, and florid, by the absorption of the atmospherical oxygen, it returns by the pulmonary veins into the left cavities of the heart.

Some have thought, that the blood which flows in the bronchial vessels, exposed to the action of the air, like the portion of this fluid which traverses the pulmonary system, loses nothing of its arterial qualities, and that, poured by the bronchial veins into the superior or descending vena cava, it was a necessary stimulus for the right cavities of the heart, of which blood entirely

* It is well known that the right lung is larger than the left, and that it is divided into three principal lobes, while the latter has only two

dark and venous would not have awakened the contractility. But even, if the experiments of Goodwin had not proved that the parietes of these cavities have a sensibility relative to dark blood, by virtue of which this stimulus is sufficient to determine their contraction, the action of the heart does not depend as closely as has been said on the impression of the blood on its substance, since it contracts, though empty, and prolongs its contractions to relieve itself of the black blood which fills it, when an animal dies of asphyxia.

Boerhaave, who admitted one sort of peripneumony depending on the obstruction of the bronchial vessels, whilst another, according to the same writer, depends on the obstruction of the pulmonary vessels, seems to justify, in some measure, the reproach, exaggerated, unquestionably, which some authors have thrown out against anatomy of having rather retarded than accelerated the progress of the Hippocratic practice of medicine. The anatomical analysis of the lungs, or the distinction of the tissues which enter into their composition, furnishes juster ideas of the difference of the inflammations by which they may be attacked. It has been seen, that of these pulmonary phlegmasiæ, the commonest and least serious consists in inflammation of the mucous membrane which lines the air passages, whilst the real peripneumony has its seat in the parenchyma of the organ, which it converts into a hard and compact mass. It is this state that anatomists have long designated by the name of *hepatisation*, because, in fact, the substance of the lung has acquired the hardness, the weight, and something of the appearance, of the liver. The same anatomical researches have shewn that pleurisy consists in inflammation of the pleura and of the surface of the lung, an inflammation which sometimes leaves no trace, but which oftener exhibits, on the opening of bodies, the pleura thickened and opaque, covered with a layer of coagulable lymph, whitish, more or less thick, or even adhering to the lung.*

There arise from the surface and from the internal substance of the lungs, a prodigious number of absorbents, which may be divided into superficial and deep-seated. The latter accompany the bronchial tubes, and penetrate into the substance of the glandular bodies situated where those air-vessels divide, but collected in greatest number towards the root of the lungs, and at the angle formed by the bifurcation of the trachea. These bronchial glands, belonging to the lymphatic system, do not differ from the glands of the same kind, and are remarkable only by their number, their size, and their habitually darkish colour. The absorbents of the lungs, after ramifying in these glands, terminate in the upper part of the thoracic duct, at the distance of a few inches from its termination into the subclavian vein. Lastly, the lungs, though endowed with a very imperfect degree of sensibility, have a pretty considerable number of nerves furnished by the great sympathetic, and especially by the eighth pair.

* These adhesions of the lung to the pleura costalis are so common, that the old anatomists considered them as a natural disposition, and called them ligaments of the lungs. It has been believed till now, that these adhesions arose from the organisation of a substance transuding from the two surfaces. Numerous dissections have convinced me, that in all the points where they are met with, the pleura has disappeared; that it is decomposed; and that whether it be at the surface of the lungs, or within the ribs and their muscles, it is produced by the act of inflammation; that it is become cellular, by the thinning of its tissue and the separation of its laminæ. The pleura thus reduced to cellular tissue, the adhesion is produced by the first intention, in the same way as in simple wounds immediately united. There is no organ that abounds more than the lungs in facts important to morbid anatomy. The variety of appearances they exhibit on the opening of bodies, is almost innumerable; and to give one instance, the pleura appears after pleurisy in five perfectly distinct conditions: 1st, in its natural state, when the disease being incipient and slight, the resolution is effected at the moment of death; 2dly, when it is red, thickened, and opaque; 3dly, when it is covered with coagulable lymph; 4thly, when it adheres; 5thly, when, in consequence of chronic inflammation, hydrothorax has taken place, &c. &c

It was long believed, on the authority of Willis, that the aerial tissue of the lungs is vesicular, that each ramification of the bronchia terminated in their substance, in the form of a small ampullula ; but at present most anatomists adopt the opinion of Helvetius. According to him, every air-vessel terminates in a small lobe, or kind of sponge fitted for the reception of air, and formed of a number of cells communicating together. These lobes, united by cellular tissue, form larger lobes, and these together form the mass of the lungs.

The tissue that connects together the different lobes is very different from that in which the ramifications of the bronchia terminate : air never penetrates into it, except when the tissue of the air-cells is ruptured. On such occasions, which are not of rare occurrence, on account of the excessive thinness of the laminæ of the air-cells of that tissue, the lung loses its form, and becomes emphysematous. Haller estimates at about the thousandth part of an inch the thickness of the parietes of the air-cells ; and as the extreme ramifications of the pulmonary vessels are distributed on these parietes, the blood is almost in immediate contact with the air. There can be no doubt that the oxygen of the atmosphere acts on the blood, under such circumstances, since it alters its qualities, and communicates to it a florid red colour, when enclosed in a pig's bladder, and placed under a vessel filled with oxygen gas.

LXXVI. *Changes produced in the air and blood by respiration.*—Every time the chest dilates, in an adult, there enter into the lungs between thirty and forty cubic inches of atmospherical air,* consisting, when pure, of seventy-nine parts in the hundred of azote, twenty-one of oxygen, and a fractional part of carbonic acid.†

When the air has been exposed, for a few moments, in the pulmonary tissue, it is expelled by the effort of expiration ; but it is diminished in quantity, and is reduced to thirty-eight inches. Its composition is no longer the same ; it contains, it is true, ·79 parts of azote, but the vital portion fit for respiration, the oxygen, has undergone a great diminution ; its proportion is only ·14 : carbonic acid forms the remaining ·07, and there are sometimes found one or two parts of hydrogen. It is, besides, affected by the addition of an aqueous vapour, which is condensed in cold weather, as it escapes at the mouth and nostrils. It is called the humour of the pulmonary transpiration. These changes, compared to those which the blood experiences in passing through the lungs, clearly shew a reciprocal action of this fluid and of the oxygen of the atmosphere. The dark venous blood which coagulates slowly, and which then disengages a considerable quantity of serum, abounding in hydrogen and carbon, and of a temperature of only thirty degrees, yields its hydrogen

* Some physiologists think that the quantity of air inspired is much less considerable. Professor Gregory, of Edinburgh, states, in his public lectures, that scarcely two inches of air enter into the lungs at each inspiration. It may be proved, however, that this calculation is inaccurate, either by drawing a full inspiration, as was done by Mayow, at the expense of a certain quantity of air contained in a bladder, or by breathing into a vessel connected with a pneumatic apparatus the air taken in by drawing a deep inspiration. Or else one may inflate the lungs of a dead body, by adapting to the trachea a stop-cock, connected with a curved tube to receive the air, under a vessel of the same apparatus. Various means have been employed to measure the capacity of the chest. Boerhaave placed a man in a tub containing water above his shoulders ; he then made him take a deep inspiration, and measured the height at which the fluid rose from the dilatation of the chest. Keill injected water into the chest of a dead body. Lastly it has been proposed to inject the bronchial tubes, and the lobular tissue into which they terminate, with fusible metal, consisting of eight parts of pewter, five of lead, three of bismuth, to which may be added one of mercury.

Menzies calculates the quantity of air admitted into the lungs at each respiration, at 43 cubic inches ; Sir H. Davy estimates it at about 17 ; Messrs. Allen and Pepys at 16½ ; and Goodwin and Abernethy at 12 only. There can be no doubt that the estimate of Menzies is too high for the natural state of the respiration ; but the quantity of air received at such inspiration must necessarily vary very much, according to the size and conformation of the individual.

† See APPENDIX, Note W, for observations on the changes induced on the air, and on the blood, by respiration.

and carbon to the oxygen of the atmosphere, to form carbonic acid and the pulmonary vapour; and as oxygen cannot enter into these new combinations without parting with a portion of the caloric which keeps it in a state of gas, the blood acquires this warmth, which is disengaged the more readily, according to the ingenious experiments of Crawford, as, by parting with its hydrogen and carbon, its capacity for caloric increases in the proportion of 10 : 11·5.

In parting with its carbon, which, by uniting with oxygen, forms the carbonic acid that is thrown out during expiration, the blood loses its dark and nearly purple colour, and becomes of a florid red, and its consistence increases, from the escape of its hydrogen and of its aqueous parts. Besides, as it absorbs a certain quantity of oxygen, it becomes spumous and light; its concrescibility and plasticity increase, and on coagulating, there is separated from it a smaller quantity of serum.

After parting with its hydrogen and carbon, and combining with oxygen and caloric, in its passage through the lungs, the blood, which is become arterial, parts with these two principles, in proportion as, in receding from the heart, it forms new combinations, and is converted into oxides of hydrogen and carbon, which, on receiving an additional quantity of oxygen, are changed into water and carbonic acid, when, on being carried along with the venous blood into the pulmonary tissue, they are exposed to the influence of the atmospherical air.

The arterial blood becomes venous by yielding its oxygen, when any cause whatever suspends or slackens its course, as is proved by the following experiment of John Hunter. He tied the carotid artery of a dog with ligatures placed at the distance of about four inches from each other: the blood contained in the portion of artery included between the two ligatures, on laying open this part of the vessel at the end of a few hours, was found coagulated, and as dark as that in the veins. The blood contained in an aneurismal sac, and which is frequently found in a fluid state, when the internal coats of the artery are but lately ruptured, becomes venous after remaining in it some time. The changes, however, which the blood undergoes in its course through the arterial system, are not very remarkable, owing to the rapidity with which it flows along those vessels: there is less difference between the blood contained in an artery near the heart and that contained in an artery at a distance from that organ, than in the blood taken from the veins near their extremities and from the great trunks which deposit it into the right auricle. The blood in the small veins resembles arterial blood; and frequently, in a very copious bleeding, the colour of the blood, which, at first, is very dark, gradually becomes less so, till, towards the end of the bleeding, it shews nearly the same qualities as the arterial; a phenomenon which, as is well observed by the English writer already quoted, depends on the more easy and rapid flow of the blood of the arteries into the veins, in consequence of the evacuation of the venous system. This observation is a complete refutation of the assertion of Bellini, who maintains, that when a vein is wounded, the blood which comes from it forms a double current, which flows out at the wound. The above opinion is maintained by highly distinguished physiologists, as Haller and Spallanzani, who support it by experiments performed on the vessels of cold-blooded animals, or on veins without valves. In bleeding at the bend of the arm, the blood cannot come from that part of the vessel which is above the wound; the valves oppose insuperable obstacles to its retrograde flow: hence it is very easy to distinguish the red blood which comes from the lower extremity of the vein from that which flows from the upper end, and which is poured into the vessel by the veins which open into it, between the puncture and the nearest valve.

In its course to the parts among which the arteries are distributed, the blood, vivified in its passage through the lungs, and fitted, as M. Fourcroy says, for a new life, loses its oxygen and caloric. Its capacity for the latter diminishes in proportion as the oxygen, by combining with hydrogen and carbon, restores it to the venous state.

This theory of the process by which the blood parts with its oxygen in its progress along the blood vessels, is rendered still more probable by recent discoveries on the nature of the diamond. This substance is the only pure carbon, and that which is called so by chemists is an oxide of carbon, which owes its dark colour to the oxygen with which it is combined. Before these experiments, it was not easy to determine the particular condition of the carbon which exists so plentifully in venous blood.

No precise calculation has yet been made of the quantity of oxygen absorbed by the venous blood, nor of the quantity employed in the combustion of hydrogen and carbon in the lungs, so as to form water and carbonic acid.*

Is the carbon in venous blood merely combined with oxygen, or is it united with hydrogen, so as to form carburetted hydrogen? It appears to me more probable, that the oxygen which is absorbed by combining with hydrogen in every part of the body produces the water which dilutes the venous blood, renders it more fluid and richer in serum than arterial blood, while, by its union with carbon, it forms an oxide that gives to the blood the dark colour which is one of its most remarkable characters. On reaching the lungs, which are real secretory organs, the water is exhaled, dissolved in the air, and forms the pulmonary transpiration; the oxide of carbon, completely decomposed by an additional quantity of oxygen, constitutes carbonic acid, which gives to the air that is expired the power of forming a precipitate in lime water.

The absorption of oxygen by the venous blood explains how the phenomena of respiration are continued into every part of the body, and produce the warmth uniformly diffused over all our organs. In proportion as the blood parts with its caloric, for which its affinity diminishes as it becomes venous, the parts which give out their hydrogen and carbon combine with it. If the lungs were the only organs in which caloric might be disengaged, the temperature of those viscera ought considerably to exceed that of other parts: experience, however, shews that the temperature of the lungs is not sensibly more elevated.

This theory of respiration, for which we are entirely indebted to modern chemistry, is contradicted by no one phenomenon. The greater the extent and capacity of the lungs, the more frequent is respiration, and the greater the warmth and vivacity of animals. Birds, whose lungs extend into the abdomen by various membranous sacs, and whose bones are hollow and communicate with the lungs, consume a great deal of oxygen, either on account of the magnitude of this respiratory apparatus, or from their frequent, and, at times, hurried respiration. On that account, the habitual temperature of their body exceeds that of man and mammiferous animals. In reptiles, on the contrary, whose vesicular lungs admit but a very small quantity of blood, and present to the atmosphere a surface of very limited extent, and in which respiration is performed with intervals of longer duration, the body is at a temperature which, naturally, never rises above seven or eight degrees.

* Instead of saying that the venous blood absorbs oxygen, it will approach nearer the state of our knowledge to believe, that the venous blood both gives off its carbon, which combines in the lungs with the oxygen of the inspired air, and absorbs a portion of oxygen, with a very variable proportion of azote. For a full view of the latest opinions on this subject, see APPENDIX, Note W.—*J. C.*

LXXVII. *Of the vital influence of the lungs in the function of respiration.*—Though the temperature or warmth of the body is generally proportioned to the extent of respiration, to the quantity of blood exposed in a given time to the action of the atmospherical air, it may be higher or lower, according to the degree of the vital energy of the lungs. These organs should not be considered as mere chemical receivers; they act on the air, digest it, as the ancients said, and combine it with the blood, by a power which is peculiar to them.* If it were otherwise, there would be nothing to prevent a dead body from being restored to life, by inflating with oxygen its pulmonary tissue. The ancients alluded to this action of the lungs on the air we breathe, by calling that air the *pabulum vitæ*. Its digestion was, they thought, effected in the lungs, in the same manner as the digestion in the stomach of other aliments less essential to life, and whose privation may be borne for a certain time, while life is endangered when the aeriform nutriment ceases to be furnished to the lungs for the short space of a few minutes.

In proof of the vitality of the lungs, and of the share which they have in producing the changes which the blood undergoes in passing through them, I may mention the experiment which proves that an animal placed under a vessel filled with oxygen, and breathing that gas in a pure state, consumes no more of it than if it was received into the chest mixed with other gases unfit for respiration. A guinea-pig placed under a vessel full of vital air, and of known capacity, will live four times longer than if the vessel contained atmospherical air. No remarkable difference is at first perceived in the act of respiration, but if the animal remains long immersed in the oxygen, his respiration becomes more frequent, his circulation more rapid, and all the vital functions are executed with more energy. The lungs separate, by a power inherent in themselves, the two atmospherical gases, and this process is effected by a pretty considerable power; for oxygen, in its combination with the blood, is with difficulty separated from azote. In fact, the blood, though in thin layers, becomes dark when exposed to the atmospherical air.

It is observed, that the purity of the air contained in the receiver is the more readily affected, as the animal placed under it is younger, more robust, and as his lungs are more capacious. Hence birds, whose lungs are very large, contaminate a considerable quantity of air, and consume more quickly its respirable part. A frog, on the contrary, will remain a considerable time in the same quantity of air, without depriving it of its oxygen.

The vesicular lungs of that reptile, as well as of all oviparous quadrupeds, are much more irritable than those of warm-blooded animals; they appear to contract at the will of the animal. The frog is without a diaphragm, attracts the air into its lungs by swallowing it by a real process of deglutition, as was proved by Professor Rafu, of Copenhagen, who killed those animals by holding their jaws asunder for a certain time. They reject the air by a contraction of the lungs, in the same manner as in man the bladder empties itself of urine.

In birds, whose diaphragm is equally membranous, and contains several openings to transmit the air into the pulmonary appendices, the parietes of the thorax are likewise more movable than in man and quadrupeds. Their pectoral muscles are more powerful, their ribs contain a joint situated in the middle of those arches which are completely ossified in that class of animals: and those two portions move on each other, forming, at their point of union, angles more or less acute, according to the distance of the sternum from the vertebral column.

* See APPENDIX, Note W

A numerous class of cold red-blooded animals, viz. fishes, have no lungs; the gills, which supply their place, are small penniform laminæ, generally four in number, situated on each side, at the posterior and lateral part of the head, covered over by a movable lid, to which naturalists give the name of operculum. The water which the animal swallows, passes, when it chooses, through the parietes of the pharynx, which contain several pretty considerable openings, is spread over the gills and the pulmonary vessels which are distributed in them, then escapes at the auricular apertures, when the animal closes its mouth and raises the opercula. It is not known whether the water is decomposed and yields its oxygen to the blood which circulates in the gills, or whether the small quantity of air that is dissolved in the water, alone serves to vivify the pulmonary blood. The latter opinion seems the most probable, if it be considered that a fish may be suffocated by closing accurately the vessel of water in which it is enclosed. The same result might, I conceive, be obtained, by placing the vessel under the receiver of an air-pump, so as entirely to exhaust it.

Respiration, which is completely under the influence of the brain, as far as relates to its mechanism, is less dependent upon it in regard to the action of the lungs on the blood, and the combination of this fluid and of its carbonaceous elements with oxygen, which is the essential object of that function. The nerves, however, have some influence on the changes which the blood experiences in the lungs during respiration, as well as on the various secretions, in the formation of which, according to Bordeu, they are of first-rate importance. M. Dupuytren ascertained by his experiments, that the division of the cervical portion of the eighth pair of nerves did not sensibly affect respiration; but the animal died with all the symptoms of asphyxia when this nerve was divided on both sides. Death took place in the course of a few minutes, when the experiment was performed on horses. Other animals did not die so soon after; dogs, for instance, have been known to live several days after the experiment. By interrupting the communication between the lungs and the brain, we paralyse the former of these organs, and it ceases to convert the venous into arterial blood.* This fluid, conveyed by the pulmonary artery, continues of a dark colour when brought to the left cavities of the heart; the arteries convey the blood without its having received its vivifying principle, in passing through the lungs, which are paralysed by having their nerves tied or divided. It is easy to conceive that all organs, for want of the stimulus which determines their action, carry on their functions imperfectly, and at last cease to act. The animal heat is likewise lowered a few degrees, as was ascertained by the above-mentioned physician, who thinks he has established as a fact, that the ligature of the nerves of the lungs does not destroy, but weakens the vital power, which enables them to take up the oxygen, and to give out the carbonic acid. The brain, therefore, possesses a double influence over the function of respiration; on the one hand, it directs its mechanism by means of the nerves which it sends to the diaphragm and to the intercostal muscles; and on the other hand, it is through the nerves which arise from the brain, that the lungs have the power of converting dark blood into arterial blood, which is the principal phenomenon of respiration.*

Experiments performed on the same subject by Dr. Legallois, subsequent to those I have just related, tend to throw some degree of uncertainty on their results. Dr. Legallois repeated these experiments publicly, in my pre-

* By dividing these nerves (the eighth pair) we paralyse the muscles of respiration, and occasion a species of asphyxia. We prevent the renewal of the air,—but we do not directly injure the vital functions of the lungs themselves. —*J. C.*

sence, and at the society of the Ecole de Médecine of Paris. After dividing the two nerves of the eighth pair, in a guinea-pig, and after having by that process brought on a state of asphyxia, he restored life and motion to the animal by opening the trachea at its anterior part. The blood of the carotids, which from red had become dark the moment the nerves were divided, assumes a brighter colour as soon as respiration is restored, and the animal lives several days after the experiment. Whence does this difference arise? does the division of the eighth pair bring on asphyxia, by occasioning spasmodic constriction of the glottis, and by impeding or even completely obstructing, the admission of the atmospherical air?*

LXXVIII. *Of animal heat.*—The human body, which is habitually of a temperature of between thirty-two and thirty-four degrees of Réaumur's thermometer,† preserves the same degree of warmth under the frozen climate of the polar region, as well as under the burning atmosphere of the torrid zone, during the most severe winters and the hottest summers. Nay, further, the experiments of Blagden and Fordyce in England, and of Duhamel and Tillet in France, shew, that the human body is capable of enduring a degree of heat sufficient to bake animal substances. The fellows of the Academy of Sciences saw two girls enter into an oven in which fruits and animal substances were being baked; Réaumur's thermometer, which they took in with them, stood at 150 degrees; they remained several minutes in the oven without suffering any inconvenience.

All living bodies have a temperature peculiar to themselves, and independent of that of the atmosphere. The sap of plants does not freeze, when the thermometer stands only at a few degrees below zero; on placing the bulb of a thermometer in a hole in the trunk of a tree during winter, the fluid sensibly rises. Now, three circumstances remain to be investigated: in the first place, what produces in living bodies this inherent and independent temperature? In the second place, how do these bodies resist the admission of a greater degree of heat than that which is natural to them? What prevents caloric, which has a perpetual tendency to a state of equilibrium, from passing into a body surrounded by a burning atmosphere? Lastly, how does a body which resists the influence of heat, withstand equally the destructive influence of an excessive degree of cold? ‡

LXXIX.—Caloric, in a latent state, or in combination with bodies, is disengaged from them, whenever they assume a different state; when, from a gaseous form they become liquid; or when from being liquid they become solid. Now, living bodies are a kind of laboratory, in which all these changes are perpetually going on; the blood which circulates in every part of the human frame is constantly receiving supplies of fresh materials; from the thoracic duct, which pours into it the chyle, abounding in nutritious particles; from respiration, which imparts to it an aeriform principle, obtained from the atmosphere; and even, in some cases, from cutaneous absorption, through which different elements are received into it. All these different substances carrying along with them into the blood a certain quantity of caloric, which is combined with them, and which is disengaged during the changes which they undergo, from the influence of the action of the organs, and gives out its caloric to the parts among which it is disengaged. Of all the principles in the blood which have the power of communicating heat to the organs, none furnishes a greater quantity than oxygen, which, during respiration, combines with the blood in the lungs. Gaseous substances, it is well known, contain most combined caloric; their state of elastic fluidity is entirely owing

* See APPENDIX, Note W.

† Between 96 and 98 of Fahrenheit.

‡ See the remarks in APPENDIX, Note Y, on the production of *Animal Heat*.

to the accumulation of that principle, and they part with it, when from any cause whatever they become liquid. It is on that account that the heat of bodies is greater, the more they have the power of impregnating their fluids with a considerable quantity of oxygen from the atmosphere. For the same reason, as was already observed, in animals that have cellular lungs, and a heart with two ventricles, the blood is of the same temperature as in man; and such animals belong, as well as man, to the great class of *warm red-blooded animals*; a class in which birds occupy the first place, from the vast extent of their lungs, which reach into the abdomen, and communicate with the principal bones of the skeleton. The capacity of the pulmonary organ of birds is not the only cause why their temperature is eight or ten degrees higher than that of man: this increase of temperature depends, likewise, on the greater frequency of their respiration, and on the velocity of their pulse; on the quickness and multiplicity of their motions, and on the vital activity which animates them. In reptiles, which have vesicular lungs, and a heart with a single ventricle, whose respiration is slow, and performed at distant intervals, the blood, though red, is of very inferior temperature to that of man. They have, from that circumstance, been called cold red-blooded animals: this numerous class includes fishes, which possess an organ supplying but imperfectly the office of lungs. In fishes, the heart, which has but a single ventricle, sends, it is true, to the gills (the organ supplying the place of lungs is so called) the whole of the blood; that fluid, however, is but imperfectly vivified in the gills, on account of the small quantity of air which can be taken in during the act of respiration. Lastly, in white-blooded animals and in plants, the combinations with the air being more difficult, the vital energy less marked, the temperature differs only by a few degrees from that of the atmosphere, and they do not endure heat or cold so well as the more perfect animals.

The lungs, as was before observed, consuming only a certain quantity of air, there is no increase of temperature, however great the quantity of oxygen contained in the atmosphere that is breathed; as a man who should take a double quantity of aliment could not receive more nourishment than if he contented himself with the quantity of food proportioned to his wants; for, as the digestive organs can extract only a certain quantity of chyle, the quantity of recrementitious matter would only be greater, if more than the due quantity of food were received into the stomach. Hence the common saying, that nourishment comes from what we digest, and not from what we eat.

The pulmonary organ may, however, act on the air with different degrees of power in robbing it of its oxygen; and when the body becomes of an icy coldness, in certain nervous and convulsive affections, this cold may depend as much on the atony of the lungs, and on the spasmodic condition of the chest, which, dilating with difficulty, does not admit the air readily, as on the spasm and general insensibility of the organs, which allow the blood to pass without affecting its component parts. It would be curious to ascertain, whether or no the air expired from the lungs of a cataleptic is deprived of less oxygen, is less impaired in purity, and contains a smaller quantity of carbonic acid, than the breath of a sound active adult. Perhaps it would be found, that in catalepsy, and other similar affections, the blood does not part with its hydrogen and carbon, that it retains its colouring principles and the different materials of the urine, which is voided in a colourless and limpid state, insipid and without smell, and in the condition of a mere serosity.

The temperature of the body is not only produced by the pulmonary and circulatory combinations, it is besides developed in several organs, in which

fluid or gaseous substances become solid, by parting with a portion of their caloric. Thus, digestion, particularly of certain kinds of food, is an abundant source of caloric ; the skin, which is habitually in contact with the atmosphere, decomposes it, and deprives it of its caloric. Lastly, caloric is produced and evolved in all parts whose molecules, affected by a double motion, in consequence of which they are incessantly being formed and decomposed, by changing their condition and consistence, absorb or disengage more or less caloric. The great activity of the power of assimilation in children is, no doubt, the cause of the habitually high temperature at that period of life.* The temperature of the body is not only one or two degrees higher at that period of life, but young people, after death, preserve, for a longer period, the remains of vital heat ; or rather, as tonicity does not so soon forsake the capillary vessels, life departing reluctantly, the combinations from which caloric is evolved continue some time, even after it is extinct. For the same reason, the bodies of persons that have died suddenly retain their warmth long, while an icy coldness seizes those who have died of a lingering disease, from the slow, gradual, and total abolition of the powers of life.

Calorification, or the disengaging of animal heat, like nutrition, takes place at all times, and may be considered as belonging to all organs. It was of the utmost consequence that the internal temperature of the human body should be nearly the same at all times. For, let us for one moment suppose, that the temperature of the blood should rise to fifty degrees of Réaumur's thermometer, its albuminous parts would suddenly coagulate, obstruct all the vessels, interrupt the circulation, and destroy life. When, therefore, from an increased activity of the nutritive combinations, a greater quantity of heat is disengaged, the animal economy parts with it, and it is taken up in greater quantity by the surrounding bodies. This accounts for the equality of the temperature of the internal parts of the body in old people and in children, notwithstanding the difference of their temperature externally. The difference consists in this, that where most caloric is produced most is given out, and though the blood and urine in old people, as well as in the young, are at thirty-two degrees, what a difference is there not between the hot and penetrating perspiration which is poured in abundance from the child, and the dryness and coldness of the skin in old people ! between the sweet and warm breath of the former, and the frozen breath of the latter ? Hence the opinion so generally received, and of such antiquity, that old people are benefited by cohabiting with the young. Thus we are told, that David had a young virgin brought to him, that he might lie with her, and get heat in his limbs that were stiffened with years.†

If it be true, that in the very act of nutrition, which converts our fluids into solids, there is disengaged a considerable quantity of caloric, the motion of nutritive decomposition, by which our solids are converted into liquids, must cause an equal quantity of heat to be absorbed. The objection is a very strong one, and not easily got over : it may be answered by observing, that all living bodies, from the instant of their formation, contain a certain quantity

* Considering the temperature of the body to be under the influence of that part of the nervous system which is distributed to the blood-vessels, as pointed out in the note on this subject in the APPENDIX, the reason will appear evident, why animal warmth is greater in young and robust subjects, than in the old and debilitated. Indeed, the temperature holds a close relation with the other changes which take place in the different textures of the body ; and it, as well as these, seems equally to result from the influence of these nerves upon the vessels to which they are distributed.—*J. C.*

† The ancients appeared to have some idea of what the moderns would do well to attend to more than they have done, if, indeed, they have attended to it at all, namely, the beneficial influence of the application of animal warmth to the system when its vital influence is either languid or sinking.—*J. C.*

of caloric, which they retain, so that this double process of acquiring heat and parting with it, the unavoidable result of nutritive composition and decomposition, merely keeps up an equilibrium, and maintains the same degree of temperature.

The blood, which becomes saturated with oxygen in the capillaries of the lungs, parts with that principle, and disengages its caloric throughout the capillary vessels of the whole body, of which each organ must set free a greater quantity, in proportion to the activity of the living principle, and to the rapidity of the circulation. The parts through which the greatest number of vessels circulates, perhaps, give out most caloric, and communicate a portion of it to the organs which receive but a small quantity of blood, as the bones, the cartilages, &c. It is easy to understand why an inflamed part, through which the blood circulates with more rapidity, and whose sensibility and contractility are much increased, is manifestly hotter to the feel of the patient and of the physician, though, as was observed by John Hunter, a thermometer applied to the inflamed part shews a scarcely perceptible increase of temperature. He injected into the rectum of a dog, and into the vagina of an ass, a strong solution of oxymuriate of mercury. Acute inflammation came on, the swollen mucous membrane formed, externally, a considerable projection. Blood flowed from the torn capillaries, yet the thermometer rose very slightly, only one degree of Fahrenheit. But however slight that increase of heat in the inflamed part, it is very sensibly felt, on account of the extreme sensibility of the organ, whose vital properties are all increased. The liveliness of impressions being proportionate to the degree of the power of sensation, one need not wonder that the patient should experience a sense of burning heat in a part in which the thermometer indicates no increase of temperature, or in which it cannot be perceived even by the touch. I have just felt a young man's hand that is swollen from chilblains; though the pain which he feels in it seems to him to be occasioned by an accumulation of caloric, his hand is colder than mine, which is of the same degree of warmth as the rest of my body, and in which I have no peculiar sensation. It may, therefore, be laid down as an axiom, that the real or thermometrical increase of heat is inconsiderable in inflammation, but that it is intensely felt in consequence of the increase of sensibility.*

What is the reason that, during the cold fit of a febrile paroxysm, a sensation of excessive cold is felt in a part in which no diminution of heat can be discovered by the touch? Whence comes the burning heat which attends inflammatory fever (*causus*)? What is the cause of the difference of the sensations attending the heat of erysipelas, bilious fevers, and phlegmon, &c.? These various sensations are owing to the different modifications of sensibility in these different diseases. Should this explanation appear unsatisfactory, let it be recollected, that however accurate may be the calculations that have been made on the subject of caloric, or of the matter of heat, the existence of caloric itself is hypothetical, and that it is not known whether caloric is a body, or whether heat is merely a property of matter.

LXXX. *Of the causes enabling the body to resist increased temperature.*—If we now inquire into the causes which enable the body to resist the admission of a degree of heat superior to that which habitually belongs to it, we shall be compelled to admit a power in all living bodies, by means of which they repel an increase of heat, and retain the same temperature. Cutaneous perspiration, it is true, acts very powerfully in lowering the temperature; and as this evaporation increases with the temperature, it should seem as if

* For some remarks on the Influence of the Nervous System in the production of Animal Heat, see APPENDIX, Note Y.

this function sufficed to moderate the heat of the body, and to restore the equilibrium.

It is a fact known since the time of Cullen,* that the evaporation of fluids, or their solution in the air, is the most powerful means of cooling bodies, and that the mercury in the bulb of a thermometer may be frozen merely by moistening it with æther, spirits of wine, or any other volatile substance, and then exposing it to a dry and warm air. This method is equally successful in its application to the human body, and the hands may be cooled to such a degree as to feel benumbed, by being frequently wetted with a spirituous fluid, and by being moved in a dry and renewed air. But though cutaneous perspiration operates in a somewhat similar manner, and though it may be ranked among the means which nature employs to preserve the animal temperature in a nearly uniform state, it must, however, be confessed, that it is not the only way in which this object is accomplished, and that it does not satisfactorily account for this phenomenon; for, the evaporation of the fluids contained in dead animal substances does not prevent their being roasted on the application of heat; and besides, fishes and frogs have been known to live and retain their temperature in mineral waters nearly of a boiling heat.†

I thought it right to repeat these experiments, and with this view, I placed living frogs in a vessel containing water at fifty degrees of temperature, and on taking them out, at the end of ten minutes, I ascertained that they were not so hot as the liquid, nor as pieces of flesh which had been put into it at the same time.

We cannot admit the opinion of Grimaud, that living bodies have the power of producing cold; for as cold is merely the absence of heat, one cannot allow a pósitive existence to a negative being.

Habit has a remarkable influence on the faculty which the body possesses of bearing a degree of heat much exceeding that which is natural to it. Cooks handle burning coals with impunity; workmen employed in forges leave the mark of their feet on the burning and liquid metal at the moment when it becomes solid by cooling. Many, no doubt, recollect the too famous instance of a Spaniard, who became so general a subject of conversation in Paris: this young man, in making his way through a house on fire, perceived that the heat was less inconvenient to him than he had imagined. He applied himself to bear, with impunity, the action of fire, and was enabled to touch with his tongue a spatula heated red hot, and to apply the soles of his feet and the palms of his hands on a red hot iron, or on the surface of boiling oil. Nothing can equal the absurdity and the exaggeration of the stories that were told of this man, except the ignorance and the want of veracity of those who invented them. The following is a correct statement of the feats of this man, who was represented as incombustible and insensible. He passes rapidly along the surface of his tongue, which is covered with saliva, a red-hot spatula, the action of which seems merely to dry it, by bringing on an evaporation of the fluids with which it is covered. After carrying the spatula from the base to the tip of his tongue, he brings it back again into his mouth, and applies it to his palate, to which it communicates a part of its heat, at the same time that it becomes moistened with saliva. This man having, in a public exhibition, carried on too long the application of the spatula,

* This celebrated physician made this discovery about forty years ago, which has thrown much light on several physico-chemical phenomena, and he published it in a dissertation, entitled, "Of the cold produced by evaporating fluids, and of some other means of producing cold," by Dr. W. Cullen.

† See Sonnerat's "Voyage to the East Indies."

the caustic effects of its heat shewed themselves; the epidermis was detached, and found coiled, like the outer covering of an onion, in the cloth which he used to wipe his mouth. He does not dip his hands and feet in boiling oil, he merely applies to the surface of the fluid his palms and his soles, and he repeats this frequently, with only a short interval between each application. When the experiment is carried on for a certain length of time, there is emitted a smell of burnt horn. No one has yet observed, that though this man's hands are not callous, the palms of these, and the soles of his feet, are cushioned with fat. A thick layer of fat, which is a bad conductor of heat, separates the skin from the subjacent aponeuroses and nerves: this circumstance, to a certain degree, accounts for his imperfect sensibility.

His pulse, during those experiments, was about a hundred and twenty; the perspiration evidently increased, and sometimes copious. Every part of his body possesses the ordinary degree of sensibility, may be destroyed by the protracted application of caustic substances, and would be consumed by fire, if applied for a sufficient length of time; and nitric acid would infallibly destroy his tongue, if he took any into his mouth, as it has been said he did. This man, therefore, in no one respect departs from the known laws of the animal economy, but, on the contrary, affords an additional proof of the influence of habit on our organs.*

LXXXI. *Causes enabling the body to resist cold.*—Before bringing to a conclusion this article on animal heat, it remains for me to explain how the body resists cold, and preserves its temperature in the midst of a frozen atmosphere. This cannot be accomplished without an increase of activity in the organs; it is only by augmenting the sum of the combinations by which caloric is disengaged, that we can succeed in making up for the loss of that principle so necessary to our existence. What is the reason that in cold weather digestion is more active, (*Hieme verò ventres sunt calidiores*, Hipp.) the pulse stronger and more frequent, and the vital energy greater? It is because heat comes from the same source, and is produced by the same mechanism, as the nutrition of the organs; and that its evolution may go on increasing, it is necessary that the secretions, nutrition, in a word, all the vital functions, should increase in the same proportion.

Observe, for a moment, a man who is exposed to a moderate degree of cold; he feels more activity, more strength, and is more nimble; he walks and exerts himself, the most violent exertions do not appear to him laborious, he struggles against the disadvantages of the debilitating influence; and provided the cold is not excessive, and the body tolerably vigorous, there is disengaged within himself a sufficient quantity of caloric to make up for the loss of that which is carried off by the air and the surrounding bodies. These general effects of cold are not disproved by what happens, when only a part of the body is exposed to it. Supposing the temperature a few degrees below zero, there is felt, at first, a sensation of cold much more inconvenient, *cæteris paribus*, than if it acted on a more extensive surface. The spot on which the cold air acts becomes affected with a painful sense of pricking, reddens, then inflames; and in this case, inflammation is evidently the result of a salutary effort of nature, which determines into the inflamed part an excess of the vital principle, so that the quantity of heat that is disengaged may correspond to that which has been abstracted. The effort of this conservatory principle is more marked than if the whole surface of the body were at once exposed to cold, because, acting wholly on a limited point, of small extent, it operates with more intensity.

* There is every reason to believe that these feats are performed by means of a composition previously applied to the parts about to be exposed to the high temperature.—*J. C.*

Beyond a certain degree, however, nature in vain struggles against cold; if severe, and if the creature exposed to it have not the power of sufficient re-action, the part becomes purple and benumbed from the loss of its caloric, vitality ceases, and it mortifies; and if the whole body is equally exposed to the influence of cold, the person is benumbed, feels a stiffening of his limbs, stammers, and, overpowered by an irresistible propensity, yields to a sleep which inevitably ends in death. By yielding thus to the illusive sweets of a perfidious sleep, many travellers have perished, after losing their way, in the mountains of the old and of the new world. Thus, two thousand soldiers of Charles the Twelfth's army perished, during a siege, in the severe winter of 1790.

To resist the effects of cold, a certain degree of strength and vigour is therefore necessary; it is consequently very injudicious to recommend the cold bath to very young children, to delicate and nervous women, to persons whose constitution is not capable of a sufficient re-action. The evil attending the injudicious use of this remedy in the cases that have just been enumerated, justifies the apparently singular terms in which Galen expressed himself: "Let the Germans (says this first of physiologists), let the Sarmatians, those northern nations as barbarous as bears and lions, plunge their children in frozen water; what I write is not intended for them."

On the other hand, if it be recollected that there is within us a power of re-action which increases with use, that motion strengthens our organs, it will be readily understood that cold acts as a tonic, whenever it is not applied to such a degree as to extinguish the vital power.

The manner in which enlightened physicians have, at all times, prescribed the cold bath, shews that they were acquainted with this tonic effect, depending, not on the application of cold, which in itself is debilitating, but on the re-action which it occasions. Hence, along with the cold bath, they are in the habit of recommending exercise, a generous wine, bark, nutritious food, and an analeptic regimen, calculated to excite a salutary re-action.

LXXXII. *Source of animal heat.*—Animal heat is, therefore, produced by the combinations of our fluids and solids in the process of nutrition; it is a function common to all the organs, for, as they all nourish themselves, so they all disengage, more or less, the caloric combined with the substances which they apply to their nutrition.

Though we are without precise information respecting the manner in which a living body resists the admission of a degree of heat exceeding that which is natural to it, one may consider cutaneous exhalation, which is increased by the use of heating substances, as the most powerful means employed by nature to get rid of the excess of heat, and to restore the equilibrium.

Lastly, the body resists cold, because the organs being rendered more active by cold, there is disengaged a quantity of caloric equal to that which is carried off by the air, or by the other substances with which the body happens to be in contact.*

LXXXIII. *Sanguifying function of the lungs.*—The rapidity of the circulation of the blood through the lungs, is equal to the velocity with which it flows in the other organs. For if, on the one hand, the parietes of the right ventricle and of the pulmonary artery are weaker and thinner than those of

* The animal economy resists a moderate degree of cold, and is even strengthened by it, owing to the re-action of the vital influence. If, however, the degree of cold be either absolutely or relatively great, the energy of the system is entirely overwhelmed by its sedative operation. The effects of cold differ not only according to its degree, but also according to the duration of exposure to it, to the state of the nervous system previous to, or during the exposure, and to the general condition of the body at the time.—*J. C.*

the left ventricle and aorta, the lungs, from their soft, easily dilated, and spongy texture, are the most easily penetrated by fluids of all our organs.

The right ventricle sends into the lungs a quantity of blood equal to that which each contraction of the left ventricle propels into the aorta, and it is not necessary to adopt the opinion of M. Kruger, that each contraction of the heart propels into the lungs, and into the rest of the body, an equal quantity of blood; for, in that case, the circulation would have been much slower, the length of the lungs being much shorter than the whole body. Nor need we say, with Boerhaave, that this circulation is much more rapid, because the same quantity of blood returns by the extremities of the pulmonary artery, and of all the other arteries of the body.

The extension of the pulmonary tissue, and the straightening of its vessels, are, no doubt, favourable to the circulation of the blood, but if the admission of air did not answer a different purpose, the circulation would not be indispensably necessary. The blood flows from the right into the left cavities of the heart, notwithstanding the collapse of the lungs, and the creases of their vessels. The air which penetrates, at all times, into the lungs, supports their tissue and the vessels which are distributed to it; so that, even during expiration, the vessels are much less creased than has been imagined by several physiologists. But the changes produced by the contact of the atmosphere, renovate this fluid, and fit it to re-excite and keep up the action of all the organs which require to be stimulated by arterial blood. If you make a living animal breathe de-oxygenated air, the blood undergoes no change by its pulmonary circulation; the left cavities of the heart are no longer duly irritated by this fluid, which preserves all its venous qualities; their action becomes languid, and with it that of all the organs; and in a little while it ceases altogether. It is revived by introducing pure air, through a tube fitted to the trachea; all the parts seem to awake out of a sort of lethargic sleep, in which they are again immersed by depriving the lungs anew of the vital air.

The chyle, mixed in great quantity with the venous blood, undergoes, in its passage through the heart and the sanguineous system, a more violent agitation: its molecules are struck together, break on each other, and, thus attenuated, become more perfectly intermingled: in its passage through the lungs, a great part of this recrementitious fluid is deposited by a sort of internal perspiration, in the parenchymatous substance of these viscera. Oxydated by the contact of the air, and re-absorbed by a multitude of lymphatic or inhalant vessels, it is carried into the bronchial glands, which are found blackened by what it there deposits of carbonic and fuliginous matter. Purified by this elaboration, it returns into the thoracic duct, which pours it into the subclavian vein, whence it soon returns to the lungs, to be there anew subjected to the action of the atmosphere; so that there is effected, through these organs, a real lymphatic circulation, of which the object is to bring the chyle to a higher degree of animalisation.

LXXXIV. *Of pulmonary exhalation.*—It will be remembered that one of the great differences between the blood of the arteries and that of the veins consists in the great quantity of serum found in this last. It is in the lungs that the separation of this aqueous part takes place and that its proportion is reduced, whether it be that oxygen gives albumen and gelatine a greater tendency to concrete, or that the serum, formed by the fixation of oxygen throughout the whole extent of the circulatory system, exhales from the arteries, and thus furnishes the matter of pulmonary exhalation. It is scarcely possible to admit the combination of oxygen with the hydrogen of the venous blood, and that water is thus formed from its elements, as happens when storms are gathering in the high regions of the atmosphere. If a similar pro-

cess can be carried on in the lungs without producing deflagration and the various phenomena attending the production of aqueous meteors, it is probable that it furnishes but a small part of the exhalation ; and that this humour, analogous to the serum of the blood, exhales, completely formed, from the arterial capillaries ramified in the bronchia and the lobular tissue of the lungs. It is believed that the quantity of the pulmonary exhalation is equal to that of the cutaneous exhalation (four pounds in twenty-four hours). These two secretions are supplemental to one another; when much water passes off by the pulmonary exhalation, the cutaneous is less, and *vice versâ*.

The surface from which the pulmonary exhalation is given out, is equal, if not superior, in extent to that of the skin ; exhalation and absorption are at once carried on from that surface, many nerves are distributed to it, and are almost exposed in the tissue of the membranes, which are extremely thin. Are the miasmata, with which the atmosphere is sometimes loaded, absorbed by the lymphatics, which, it is well known, have the power of taking up gaseous substances ; or do they merely produce on the nervous and sensible membranes of the bronchia, and of the lobular tissue, the impression whence the diseases of which they are the germ arise ?

A part of the caloric which is disengaged in the combinations which oxygen undergoes in the lungs, is taken up in dissolving and reducing into vapour the pulmonary exhalation, which is the more abundant according as respiration is more complete. Pulmonary exhalation should be carefully distinguished from the mucous matter secreted within the bronchia and trachea, and which is thrown up by a forcible expiration, and forms the matter which we expectorate.

LXXXV. *Of asphyxia.**—The term asphyxia, though merely indicating a want of pulse, is applied to any kind of apparent death occasioned by an external cause, and suspending respiration, as submersion, strangulation, the diminution of oxygen in the air inhaled, &c. The only difference between real death and asphyxia is, that in this last state the principle of life may yet be re-animated, whilst in the other it is completely extinct.

Asphyxia takes place in drowning, because the lungs, deprived of air, no longer impart to the blood which passes through them the qualities essential to the support of life. The water does not find its way into these viscera ; the spasmodic closing of the glottis prevents its getting into the trachea and its branches. Yet there is found a small quantity in the bronchia after drowning, always frothy, because air has mixed with it, in the struggles which precede asphyxia. If the body remain long under water, the spasmodic state of the glottis ceases, water passes into the trachea and fills the lungs. The anatomical examination of a drowned body shews the lungs collapsed, and in the state of expiration ; the right cavities of the heart, the venous trunks which terminate in them, and, generally, all the veins, are gorged with blood,† whilst the left cavities and the arteries are almost entirely empty. Life ceases in this kind of asphyxia, because the heart has sent to the different organs, and especially to the lungs, no blood that is not deficient in the qualities necessary to their action ; and, perhaps, also, because the venous blood that is accumulated in the tissues, affects them by its oppressive and deadly influence. On that account, the best way of restoring the drowned to life is to blow pure air into their lungs. This is done by means of bellows adapted to a canula introduced into the nostril ; if a proper apparatus can-

* See APPENDIX, Note W.

† Hence the dark and livid colour of the skin and conjunctiva. This last membrane is frequently injected with dark blood ; the very delicate veins of the brain are considerably dilated, and this viscus is distended with venous blood.

not be procured, one might blow with his mouth into that of the drowned person, or into his nostrils, by means of a tube; but air so expired, having already undergone the process of respiration, contains a much smaller quantity of oxygen, and is much less fitted to excite the action of the heart. There remain several other less efficacious remedies, such as friction, bronchotomy, glysters, fumigations and suppositories, stimulating errhines, and especially ammonia; stimulants taken into the mouth and stomach, the application of fire, bleeding, the bath, electricity, and galvanism.

The redness and lividity of the face in persons who are hanged, had led to the opinion, that death, in such cases, was from apoplexy; but it appears that in the asphyxia from strangulation, as in that from drowning, death is caused by the interception of the air. To prove this, Gregory performed the following experiment: he opened the trachea of a dog, and passed a noose round his neck, above the wound. The animal, though hanged, continued to live and to breathe; the air entered and came out alternately, at the small opening: he died when the constriction was applied below the wound. A respectable surgeon, who served in the Austrian army, assured me, that he had saved the life of a soldier, by performing upon him the operation of laryngotomy a few hours before his execution.

Persons who are hanged may die, however, from dislocation of the cervical vertebræ, and from the injury done at the same time to the spinal marrow. Louis, it is well known, ascertained, that of the two executioners in Lyons and Paris, the one despatched the criminals he executed by dislocating the head at its articulation with the neck, while the other executioner destroyed them by inducing asphyxia.

Of the different mephitic gases unfit for respiration, some appear to bring on asphyxia, merely by depriving the lungs of the vital air necessary to the support of life, while others evidently affect the organs and the blood which fills them, by their poisonous and deleterious influence.

One may mention, among the former, carbonic acid: in the asphyxia occasioned by this gas, and which, of all others, is the most frequent, the blood preserves its fluidity, the limbs their suppleness, and the body its natural warmth, or even a greater degree of warmth, for some hours after death; for, this kind of asphyxia occurring always in a very hot situation, the body, deprived of life, admits an excess of caloric, such as would have been resisted if the vital power had not been suspended. However, in this asphyxia, as in the preceding, the lungs remain uninjured; the right cavities of the heart and the venous system are gorged with a dark but fluid blood. In the asphyxia, on the other hand, that is occasioned by sulphuretted or phosphuretted hydrogen, &c., or by certain vapours whose nature is not well understood, and which escape from privies, or from vaults in which a number of dead bodies undergo putrefaction; there are frequently found in the lungs dark and gangrenous marks, and death seems the effect of a poison which is the more active, as its particles, exceedingly divided and in a gaseous state, are more insinuating, and affect, throughout its whole extent, the nervous and sensible surface of the lungs.

Inebriation seldom goes the length of bringing on asphyxia; it most commonly produces a stupor readily distinguished from the affection treated of in this article, by the perceptible, though obscure pulse, and by the motions of respiration, though these are rare and distinct. On this account, M. Pinel, in his *Nosographie Philosophique*, has placed inebriation, and the different kinds of asphyxia, in two separate genera of the class neuroses. It is conceivable, however, that the muscular irritability may be so far impaired by the

use of spirituous liquors, that the heart and diaphragm might lose the power of contraction, which would bring on complete asphyxia.

The glottis, through which the atmospherical air passes in its way to the lungs, is so small, that it may be readily obstructed, when the epiglottis rising at the moment of deglutition, the substance that is swallowed stops at the orifice of the larynx: a grape seed may produce this effect; and it was in this manner, we are told, that Anacreon, that lovely poet of the graces and of voluptuousness, came by his death. Gilbert, the poet, died in the same way, after a long and painful agony. A great eater, in the midst of a feast went into an adjoining room, and did not return, to the great surprise of all the guests. He was found stretched on the floor, without any sign of life. Help, given by ignorant people, was of no use. On opening the body, a piece of mutton was found fixed in the larynx, and completely stopping the passage of the air.

Sometimes a child is born, and shews no signs of life. When it is probable, from the circumstances of the delivery, that there has been no organic injury decidedly mortal, it must be considered as a case of asphyxia from weakness; and all means employed that are recommended in such cases, especially blowing in air into the lungs, by means of a tube introduced into the mouth or nostrils. It is thus that the Prophet Elisha restored to life the son of the Shunamite, as we are informed in the second book of Kings, chapter the fourth.

LXXXVI. *Of certain phenomena of respiration, as sighing, sobbing, yawning, sneezing, coughing, hiccup, laughing, &c.*—When the imagination is strongly impressed with any object, when the vital functions are languid, the vital principle seems to forsake all the organs, to concentrate itself on those which partake most in the affection of the mind. When a lover, in the midst of an agreeable reverie, sighs deeply, and at intervals, a physiologist perceives in that expression of desire, nothing but a long and deep inspiration, which, by fully distending the lungs, enables the blood collected in the right cavities of the heart to flow readily into the left cavities of that organ. This deep inspiration, which is frequently accompanied by groans, becomes necessary, as the motion of respiration, rendered progressively slower, are no longer sufficient to dilate the pulmonary tissue.

Sobbing differs from sighing merely in this, that though the expiration is long, it is interrupted, that is, divided into distinct periods.

Yawning is effected in the same manner; it is the certain sign of ennui,—a disagreeable affection, which, to use the expression of Brown, may be considered as debilitating, or *asthenic*. The fatigued inspiratory muscles have some difficulty in dilating the chest, the contracted lungs are not easily penetrated by the blood which stagnates in the right cavities of the heart, and produces an uneasy sensation, which is put an end to by a long and deep inspiration; the admission of a considerable quantity of air is facilitated by opening the mouth widely by the separation of both jaws. One yawns at the approach of sleep, because the agents of inspiration, being gradually debilitated, require to be roused at intervals. One is, likewise, apt to yawn on waking, that the muscles of the chest may be set for respiration, which is always slower and deeper during sleep. It is for the same reason that all animals yawn on waking, that the muscles may be prepared for the contractions which the motions of respiration require. The crowing of the cock, and the flapping of his wings, seem to answer the same purpose. It is in consequence of the same necessity, that the numerous tribes of birds in our groves, on the rising of the sun, warble, and fill the air with harmonious

sounds. A poet then fancies he hears the joyous hymn by which the feathered throngs greet the return of the god of light.

While gaping lasts, the perception of sounds is less distinct; the air, as it enters the mouth, rushes along the Eustachian tubes into the tympanum, and the membrane is acted upon in a different direction. The recollection of the relief attending the deep inspirations which constitute gaping, the recollection of the grateful sensation which follows the oppression that was felt before, involuntarily leads us to repeat this act whenever we see any one yawning.

Sneezing consists in a violent and forcible expiration, during which the air, expelled with considerable rapidity, strikes against the tortuous nasal passages, and occasions a remarkable noise. The irritation of the pituitary membrane determines, by sympathy, this truly convulsive effort of the pectoral muscles, and particularly of the diaphragm.

Coughing bears a considerable resemblance to sneezing, and differs from it only in the shorter period of duration, and the greater frequency of the expirations; and, as in sneezing, the air sweeps along the surface of the pituitary membrane, and clears it of the mucus which may be lying upon it, so the air, when we cough, carries along with it the mucus contained in the bronchia, in the trachea, and which we spit up. The violent cough at the beginning of a pulmonary catarrh, the sneezing which attends coryza, shew that the functions of the animal economy are not directed by an intelligent principle, for such an archæus could not mistake, in such a manner, the means of putting a stop to the disease, and would not call forth actions which, instead of removing the irritation and inflammation already existing, can only aggravate them.

Laughing is but a succession of very short and very frequent expirations. In hiccup the air is forcibly inspired, enters the larynx with difficulty, on account of the spasmodic constriction of the glottis; it is then expelled rapidly, and striking against the sides of that aperture, occasions the particular noise attending it.

I shall, on another occasion, explain the mechanism of sucking, of panting, and of the efforts by which the muscles of the thorax fix the parietes of that cavity, so that it may serve as a fixed point of the other muscles of the trunk and of the limbs.

Respiration is besides employed in the formation of the voice; but the voice, and the different modifications of which it is capable, will form the subject of a separate chapter.*

* The author has neglected to notice the state of respiration during the more active voluntary motions. Muscular exertion, especially when considerable, is preceded by a full inspiration, immediately upon which the glottis is firmly closed and the abdominal muscles contracted. At this moment the diaphragm is relaxed; but the complete closure of the glottis, and contraction of the abdominal muscles engaged in respiration, furnish a fixed basis of action to the muscles employed in great exertions. At the same time that the glottis is closed, the muscles of the face participate in the action, in consequence of being supplied with branches of the respiratory order of nerves, (see the Notes in the APPENDIX on the different Orders and Functions of the Voluntary System of Nerves), and the jaws are forcibly pressed together. By this action of the muscles engaged in respiration, the chest is rendered capacious, the circulation through the lungs facilitated, and the strength thereby greatly increased because the trunk of the body is thus rendered immovable in respect of its individual parts, the muscles arise from fixed points, and consequently wield the limbs with their full energy. Haller appears to be correct, in concluding that, under a state of increased action of the muscles, the flow of blood becomes greater towards the head: the nervous energy is increased, by means of this augmented flow, and supplied so as to keep up the muscular action for a longer period than otherwise would be the case. During violent exertions, also, the return of blood from the brain is in some degree impeded.

The physiological state of muscular actions, as they are related to the mechanical function of respiration, is very happily described by Shakespeare, where he makes the fifth Henry encourage his soldiers at the siege of Harfleur:—

LXXXVII. *Of cutaneous perspiration.*—An abundant vapour is continually exhaling from the whole surface of the body, and is called the insensible perspiration, when in a state of gas in the air which holds it in solution, it then eludes our sight; it is called sweat, when in greater quantity and in a liquid form. Sweat differs, therefore, from insensible perspiration, only by the condition in which it appears; and it is sufficient for its production, that the air should be incapable of reducing it into vapour, whether from an increased secretion by the skin, or from the dampness and consequent diminished solvent powers of the atmosphere. The insensible perspiration is constantly escaping through the innumerable pores in the parietes of the minute arteries of the integuments; it oozes in the interstices of the scales of the skin; the air which immediately surrounds our body becomes saturated with it, and carries it off as soon as it is renewed. There is the greatest resemblance between the cutaneous perspiration and the pulmonary exhalation; both are mere arterial exhalations; and the mucous membrane which lines the canals along which the air is transmitted, is a mere prolongation of the skin into those organs and into the digestive tube. The surface from which the cutaneous perspiration is exhaled, is not quite so considerable as that from which the pulmonary exhalation arises, since it is reckoned at only fifteen square feet in a man of middle size. These two secretions are supplementary to each other; the increase of the one is generally attended with a sensible diminution of the other; lastly, the mucous membrane of the intestinal canal, besides secreting mucus, exhales likewise a fluid which increases much in quantity when the cutaneous perspiration is languid,—as is proved by the serous diarrhœas so frequently occasioned by a suppressed perspiration. It must be owned, however, that notwithstanding those analogies of structure and function in the skin and mucous membranes, there exists perhaps a still more intimate connexion between its action and that of the organs which secrete the urine: it has always been observed, that when this last fluid is scanty, there is a greater cutaneous perspiration, and *vice versâ.*

If we examine with a microscope the naked body, exposed during summer to the rays of a burning sun, it appears surrounded with a cloud of steam, which becomes invisible at a little distance from the surface. And if the body is placed before a white wall, it is easy to distinguish the shadow of that emanation. We may likewise satisfy ourselves of the existence of the cutaneous perspiration, by the following experiment: hold the tip of the finger at the distance of the twelfth part of an inch from a looking-glass, or any other highly polished surface, its surface will soon be dimmed by a vapour condensed in very small drops, which disappear on removing the finger. One may, in this manner, ascertain that the cutaneous perspiration varies in quantity in different parts of the surface of the body; for, on placing the back of the hand before a looking-glass, the latter will be covered by no vapour.

No function of the animal economy has been the subject of more investigation, nor has any excited the attention of more accurate and indefatigable physicians, than the secretion now under consideration. From the time of Sanctorius, who, in the beginning of the seventeenth century, published in his immortal work, *Medicina Statica*, the result of experiments carried on for

"Stiffen the sinews, summon up the blood,
* * * * * *
Now set the teeth, and stretch the nostrils wide:
Hold hard the breath, and bend up every spirit
To his full height."

In vomiting also, and in the action of expelling the fæces and contents of the bladder, the thoracic and abdominal muscles of respiration are brought into action, and the glottis closed.—*J. C.*

thirty years, with a patience which very few will imitate,—to that of Lavoisier, who, jointly with Séguin, aided by the resources of the improved state of chemistry, instituted an examination of the insensible perspiration,—we find engaged in this inquiry, Dodart, who, in 1668, communicated to the Academy of Sciences, which had been founded but a short time, the result of his observations at Paris, under a climate different from that of Venice, where Sanctorius lived :—Keill, Robinson, and Rye, who repeated the same experiments in England and Ireland :—Linnings, who performed his in South Carolina ; and several physiologists of no less merit, as Gorter, Hartmann, Arbuthnot, Takenius, Winslow, Haller, &c., who all aimed at ascertaining, with more precision than had been done by Sanctorius the variations in the cutaneous perspiration, according to the climate, the season of the year, the age, the sex, the state of health or disease, the hour of the day, and the quantity of other secretions.

According to Sanctorius, of eight pounds of solid and liquid aliments taken in twenty-four hours, five were carried off by the perspiration, and only three in excrement and urine. Haller conceives this calculation to be exaggerated ; Dodart, however, carried it still further, and maintained that the relation of the perspiration to the solid excrements was as seven to one.

In France, and in temperate climates, the quantity of the cutaneous perspiration and of the urine is nearly the same ; it may be estimated at between two and four pounds in the twenty-four hours. We perspire most in summer, and void most urine in winter. The perspiration, like every other secretion, is in smaller quantity during sleep than while we are awake ; in old age than during infancy ; in weak persons, and in damp weather, than under the opposite circumstances.

The perspiration may be said to be in a compound ratio of the force with which the heart propels the blood into the minute capillary arteries, of the vital energy of the cutaneous organ, and of the solvent powers of the atmosphere. The strongest and most robust men perspire most ; some parts of the skin perspire more than others, as the palms of the hands, the soles of the feet, the arm-pits, &c. When the air is warm, dry, and frequently renewed, cutaneous perspiration is greater, and the necessity of taking liquid aliment is more urgent, and more frequently experienced : in summer, as every body knows, a profuse perspiration is brought on by passing from the heat of the sun into the shade ; and on no occasion is a copious sweat more easily brought on, than by taking exercise in summer, when, on the approach of a storm, the atmosphere, containing a small quantity of vapours, and warm from the rays of the sun, which shews itself now and then, surrounded by the clouds, is little capable of dissolving the insensible perspiration.

The skin may be covered with sweat, without any increase of the cutaneous perspiration ; this may happen from dampness in the air, or from its being imperfectly renewed. It must be owned, however, that sweating is more frequently occasioned by an increase of the insensible perspiration, and that the warmth of the bed which excites it, acts by increasing the power of the organs of circulation, and the energy of the cutaneous system. The body is weakened by sweating, which is seldom the case with the insensible perspiration. A profuse sweat is attended with a very speedy exhaustion ; thus, in hectic fever, in the *suelte* (*sudor anglicus*,) and other affections equally dangerous, it is the cause of a wasting almost universally fatal.

The matter of the insensible perspiration, and of the sweat, is, in great measure, aqueous. Like the urine, it holds in solution several salts, also the volatilised recrementitious matter of animal substances, sometimes even acids,

as in the case in which Berthollet detected the phosphoric acid in children affected with worms, in pregnant women, in nurses, from whom there exhales an odour manifestly acid. It may contain ammonia, and, on certain occasions, the smell enables us to discover that alkali in the sweat or perspiration.

The air which constantly surrounds our body does not merely dissolve the aqueous vapour which arises from it; but several physiologists very reasonably conjecture, that the ozygen of the atmosphere may combine with the carbon of the blood brought to the skin by the numerous vessels which are sent to it, and likewise with the gelatine forming the substance of the rete mucosum of Malpighi.

The experiments of Jurine, of Tingry, and of several other naturalists, shew that carbonic acid is constantly formed on the surface of the skin, so that the skin may be considered as a supplementary organ to that of respiration; and in that point of view, one may compare to it the mucous membranes which are in contact with the atmospherical air in the nasal fossæ, and in the intestinal canal which they line.

The cutaneous perspiration is, likewise, as was before mentioned, a powerful means of cooling the body, and of keeping it, while living, in a uniform temperature. The water which is exhaled from the whole surface of the body, carries off from it, in passing into vapour, a considerable quantity of caloric; and it is observed, that every thing which increases the production of caloric gives rise to a proportionate increase of the cutaneous perspiration, and of the pulmonary exhalation; so that a constant equilibrium being kept up between its production and escape, the animal warmth always remains nearly the same*.

To conclude, the extremities of the nerves of our organs of sensation are all moistened by a fluid varying in quantity, and which maintains them in a softened state, favourable to the exercise of their functions. It was likewise necessary that the membrane in which the sense of touch resides should be habitually kept moist by a fluid that should penetrate it throughout: this use of the insensible perspiration is not less important than the preceding, on which physiologists have bestowed most attention.

* If transpiration be restrained or stopped, and if the causes productive of heat act with intensity, it would appear that the temperature of the surface of the body rises some degrees; hence the reason that the heat is so distressing in those diseases which are characterised by diminished transpiration, and in which the dryness of the skin is so remarkable, as erysipelas, erythema, &c. MM. Berger and Delaroche have supposed that they have seen, when the air of a room is saturated with humidity, and rendered very warm, that the human body exposed to this atmosphere acquires a higher temperature than is natural to it; the cutaneous and pulmonary transpiration either being altogether arrested, or imperfectly performed. For farther observations on this subject, see APPENDIX, Note Z.—*J. C.*

CHAPTER V.

OF THE SECRETIONS.

LXXXVIII. *Of the animal fluids.*—The animal fluids were formerly divided into *recrementitious*, *excrementitious*, and *excremento-recrementitious :* this division, founded on the uses to which the fluids are subservient, is preferable to any that has since been adopted, and in which they are ranked according to their nature.

The first class remain in the body, and are employed in its nutrition and growth ; such as the chyle, the blood, the serosity which lubricates the surface of the pleura, of the peritonæum, and of the other membranes of the same kind. The second kind are ejected from our body, and cannot remain long within it without danger ; such as the urine, the matter of insensible perspiration and of sweat. Lastly, those of the third class partake of the nature of the two preceding, and are in part rejected, while another part is retained and employed in the support and growth of the organ ; this is the case with the saliva, the bile, the mucus of the intestines, &c. If one affected to be very minutely scrupulous, one might consider all the animal fluids as recremento-excrementitious. The chyle and the blood, which are so very nutritious, contain an abundance of heterogeneous and excrementitious parts ; the urine, which of all our fluids is that which may, with most propriety, be termed such, contains likewise aqueous parts, which, while it remains in the bladder, the lymphatics absorb and carry into the mass of the fluids.

Of all the modern divisions, Fourcroy's is the best ; Vicq-d'Azyr acknowledged its superiority over that proposed by Haller in his Physiology. Fourcroy admits six classes of fluids : 1st, those which hold salts in solution, as the sweat and urine,—he gives the name of *saline* to such fluids ; 2d, inflammable *oily* fluids, all possessing a certain degree of consistence and concrescibility, as fat, and the cerumen of the ears, &c. ; 3d, the *saponaceous* fluids, as the bile and milk ; 4th, the *mucous* fluids, as those which lubricate the internal coat of the intestinal canal ; 5th, the *albuminous* fluids, among which one may rank the serum of the blood ; 6th, the *fibrinous* fluids, containing fibrina, as the fluid last mentioned.*

In proportion as we advance in our knowledge of animal chemistry, the defects of these divisions become more and more evident. In short, the animal fluids are so compound, that there is not one which does not, at once,

* Berzelius distinguishes the fluids formed from the blood into *secretions*, properly so called, and *excretions*, or those which are directly discharged from the body. The former are destined to perform a farther office in the animal economy—all of these are alkaline ; they are the bile, the saliva, and the fluid, which is secreted on the mucous and serous surfaces. In the latter division acids predominate : the excretory fluids embrace the urine, the cutaneous and pulmonary transpiration, and the milk. Magendie divides the secretions into exhalations, *follicular* secretions, and *glandular* secretions. See APPENDIX, Note AA, for farther observations on this subject.—*J. C.*

belong to several of these classes, and whose prevailing element is not sometimes exceeded in quantity by materials which commonly form but a small part of them.

LXXXIX. *Of the blood.*—The blood is the reservoir and the common source of the fluids; these do not exist in the blood, with the qualities which characterise them, unless, after having been previously formed by the secretory organs, they have been absorbed by the lymphatics, and conveyed, with the chyle and lymph, into the circulatory system. Let us shortly attend to its nature, although this belongs more especially to the department of chemistry. The blood is red in man and in all warm-blooded animals, and even in some whose temperature is not very different from that of the atmosphere, as in fishes and reptiles. This colour, of a deeper or lighter shade, according as the blood is drawn from an artery or a vein, varies in its degree of intensity according to the state of health or weakness. It is of a deep red in strong and active persons, pale and colourless in dropsical patients, and whenever the health is weak. By its colour, one may judge of all its other qualities. Its viscidity is greater, its saline taste more marked, its peculiar smell stronger, when its colour is deep. This colour is produced by a prodigious number of globular molecules, which move and float in an aqueous and very liquid fluid. When the blood is pale, the number of these molecules diminishes: they seem to be dissolved in cachexiæ.

Does the microscope, which affords the only method of perceiving them, enable one to determine their bulk and their figure? Sir E. Home considers the red particles to be $\frac{1}{5000}$ of an inch in diameter. Leeuwenhoek, who brought forward the idea of their being so minute, by his calculation that they were one millionth part of an inch in size, thought them spherical. Hewson says they are annular, and have an opening in their centre. Others compare them to a flattened lentil, with a dark spot in the middle. They are solid, and formed by a nucleus or red point, covered over by a membranous vesicle, which appears to be readily formed and destroyed.*

XC. *The constituent parts of the blood.*—The blood, when no longer in the course of the circulation, and on being received into a vessel, parts with its caloric, and exhales at the same time a powerful smell, a gas to which, according to some physiologists, (Moscati, Rosa, &c.) it owes its vital properties, and the absence of which is attended with a loss of its vitality; so that its analysis cannot furnish facts applicable to the explanation of the phenomena of health and disease. This odour, extremely strong in carnivorous animals, is very distinguishable in man, especially in arterial blood. I remember retaining it a whole day in my throat, after removing the dressings, and suppressing a hæmorrhage occasioned by a relaxation of the ligatures, a week after the operation for popliteal aneurism. Unless the blood is prevented by agitation from coagulating as it cools, its consistence increases, and on being laid by, it separates into two very different parts, the one aqueous, more or less red, heavier than common water, and evidently saltish; this is called the serum, consisting of water, in which are dissolved albumen, gelatine, soda, phosphates and muriates of soda, nitrate of potash, and muriate of lime.

Serum, though bearing some analogy to the albumen of egg, differs from it, in forming, on coagulating, a less solid and less homogeneous mass. The albumen is evidently mixed with a portion of transparent gelatine, not coagulable by heat. Albumen has so great an attraction for oxygen, that it is fair to presume that the serum absorbs oxygen and combines with it, through the very thin parietes of the air-cells of the lungs, and that it gives to arte-

* See the APPENDIX, Note B B.

rial blood that spumous appearance which is one of its distinguishing characters. This oxidisement, and the fixation of the caloric which accompanies it, equally increase its consistence. It does not, however, coagulate, because it is kept in perpetual motion by the circulatory action, and is diluted by a sufficient quantity of water; because the animal temperature, which never exceeds thirty-two or thirty-four degrees, cannot give a solid form to albumen, which coagulates only at fifty degrees of Réaumur's thermometer; and lastly, because as serum contains a certain quantity of uncombined soda, which enables it to turn green vegetable blues, this alkali concurs in keeping the albumen in a dissolved state, which it renders fluid when it has been coagulated by the acids, by heat, or by alcohol.

Amid the serum, and on its surface, there floats a red cake, spongy and solid (*insula rubra*), which, by repeated washing, may be separated into two very distinct parts. The one is the cruor, or the colouring matter, which mixes with the water; it is a more highly oxygenated and more concrescible albumen than that of the serum; it holds in solution soda, as well as phosphate of iron, with an excess of iron.* The other is a solid and fibrous substance, which, after being repeatedly washed, has the appearance of felt, the filaments of which cross each other, are extensible, and very elastic. This third part of the blood is called *fibrina;* it is very similar in its nature to muscular fibre, and, like it, gives out, on distillation, a considerable quantity of carbonate of ammonia. Fibrina does not exist in the blood in a solid form, but in a state of solution, and combined with the other constituent parts of the fluid, as is indicated by the appropriate expression of liquid flesh (*chair coulante*), first used by Bordeu in speaking of the blood.

XCI. *Of the ultimate elements of the blood.*—If the blood be exposed to the action of fire, if it be calcined and reduced to powder, and if this pulverised substance be exposed to a magnet, the presence of iron will be manifestly seen by the magnetic attraction. Authors do not agree in their accounts of the quantity of iron contained in the blood. Menghini says there is one part in the hundred; others that it is in the proportion of 1 to 303; so that it is probable that this constituent principle of the blood, like all the materials of our fluids, may vary in quantity according to different circumstances.

Blumenbach justly observes, that iron is found only in calcined blood; that none is to be found if it be slowly dried. This peculiarity is no longer surprising, since M. Fourcroy has shewn that iron existed in the blood, in combination with the phosphoric acid, and formed with that acid a phosphate of iron, with an excess of its base. This salt becomes decomposed by calcination, the iron is set free, and is acted upon by the magnet. Physiologists attribute the colour of the blood to the presence of the oxide of iron in that fluid.

* It is a more oxygenated and a more coagulable albumen than that of the serum. The colouring part of the blood, when incinerated, after giving off a considerable quantity of ammonia during the combustion, leaves ashes which, according to Berzelius, are only a hundredth part of its weight, and which contain 55 parts of the oxide of iron, 8½ of the phosphate of lime, a little of magnesia, 17½ parts of lime, and 16½ of carbonic acid. The oxide of iron is neither found in the ashes of the coagulable part of the serum, nor in those of the fibrine. Berzelius, however, further informs us, that the serum, although able to dissolve a small portion of the oxides of iron, but not of its phosphates, does not acquire a red colour by this weak solution, and that he has neither detected iron nor lime in the entire blood, although both are so abundant in its ashes. He therefore concludes, that the blood contains the elements only of the phosphate of iron, and of lime and magnesia, and of the carbonate of lime, united very differently from their combination in these salts. Nor is it unlikely that these salts are formed during incineration, from the presence of the elements of their respective bases, the other elements being furnished during incineration. The existence of iron in the colouring particles of the blood, and its absence from the serum, have been confirmed by the recent experiments of several chemists on the continent.—*J. C.*

It has been the received opinion, that the red colour of the blood is owing to the presence of phosphate of iron, which being conveyed of a white colour into the blood, along with the chyle, meets with the pure soda, by which it is dissolved, and from which it receives its colour; the colour of the blood is likewise owing to the oxidisement of the metallic portion, which is in very considerable quantity in that salt. This solution of the phosphate of iron by soda, the oxidisement of the excess of iron, and the absorption of oxygen by albumen, constitute, in an especial manner, *hematosis* or *sanguification*, which is principally carried on in the lungs.

This opinion of Fourcroy respecting the source whence the blood acquires its red colour, has, since his time, been adopted by some, and combated by other, physiologists. It is now entirely abandoned, because it is known that the colouring part of this fluid may be obtained separately, and entirely exempt from iron. This colouring portion of the blood, according to M. Vauquelin, does not change its colour when tested with gallic acid,—a farther proof that it contains no iron.*

The respective proportion of the three parts into which the blood separates spontaneously, varies considerably. The serum constitutes about one-half or three-fourths of the fluid; the colouring matter and fibrina are in inverse ratio of the serum; and it is observed, that the more brilliant and red the colour of the blood, the greater the proportion of the fibrous part. The pale, aqueous, and colourless blood of a dropsical patient contains very little fibrina. In putrid or adynamic fever, in which bleeding, as is universally known, is improper, I have sometimes seen the blood containing but a small portion of fibrina, and very slow of coagulating; its texture seemed to suffer from the affection under which the muscular organs were evidently labouring. In inflammatory diseases, on the contrary, the plastic power of the blood is augmented, the fibrina is in greater quantity, even the albumen coagulates spontaneously, and forms a crust above the serum, which is always in smaller quantity.†

XCII. *Of the changes in the blood.*—The fluids not only undergo changes in their composition, in their qualities and nature, when the action of the solids is itself altered, but even the absorbent system may introduce into the mass of our fluids heterogeneous principles, evidently the cause of several diseases. In this manner, all contagions spread, the virus of small-pox, of syphilis, of the plague, &c. Thus, in time, the habitual use of the same aliment produces in our fluids a *crasis* or peculiar constitution, which has on organised solids an influence acting even on the mind.

A purely vegetable diet conveys into the blood, according to Pythagoras, bland and mild principles: this fluid excites the organs in a moderate degree, and this check over the physical excitement facilitates the observance of the laws of temperance, the original source of all virtues. These observations of ancient philosophy on the influence of regimen have, doubtless, led their authors to exaggerated inferences; but they should not be considered as altogether unsupported. The carnivorous species are marked by their strength, their courage, and their ferocity; savages who live by hunting, and who feed on raw, bloody, and palpitating flesh, are the most ferocious of

* Since the time of Fourcroy, chemists have differed widely respecting the presence of iron in the red particles of the blood. The recent researches, however, of some continental inquirers seem to have settled the question in the affirmative. See APPENDIX, Note B B.—*J. C.*

† According to Mr. Brande and Sir E. Home, both venous and arterial blood contain carbonic acid in the proportion of two cubic inches of the gas for each ounce of blood. This acid disengages itself immediately when a portion of the warm blood is placed in an air-pump. Dr. Davy has, however, recently contended that the blood contains little or no carbonic acid. See APPENDIX, Note B B, for farther remarks respecting the Blood.

men; and in our own country, in the midst of those scenes of horror which we have witnessed, and from which we have suffered, it was observed that butchers were foremost in the massacres, and in all the acts of atrocity and barbarity. I know that this fact, which was uniformly noticed, has been explained by saying that the habit of slaying animals had familiarised them to shed human blood. But though I do not deny the existence of this moral cause, which certainly operates, I think I may add to it as a physical cause, the daily and plentiful use of animal food, and the breathing an air filled with emanations of the same kind, which contributes to their *embonpoint*, which is sometimes excessive.

As the plasticity and concrescibility of the blood are diminished in asthenic diseases, or of debility, as putrid fevers and scurvy, two causes may be assigned for the hæmorrhages which come on in those diseases, viz. the relaxed state of the vessels, and the dissolution of the blood. In scurvy the tissue of the capillaries is relaxed, its meshes enlarged, red blood passes into them, transudes through their parietes, and forms scorbutic spots. I have sometimes seen those ecchymoses or sanguineous cutaneous transudations extend under the skin of the whole of one lower extremity. Petechiæ, in putrid fever, are formed in the same manner, and depend, likewise, on the relaxation of the minute vessels, and on the greater fluidity of the blood, whose molecules are less coherent, and more readily separated from each other.

In the summer of the year 1801 I amputated the arm of an old man of sixty, on account of a corroding and varicose ulcer, which for thirty years had occupied a part of the fore arm, and extended to the elbow. All who were present at this operation observed that the blood which flowed from the arteries was not nearly so red as that from the arteries of a young man, whose thigh had just been taken off on account of a scrofulous caries of the leg; that the venous blood was entirely dissolved, purple, and similar to a weak dye of logwood. The blood did not coagulate like that of the young man; it became fluid, and was converted into a serum, containing a few colourless clots.

Those who have endeavoured to find in the changes undergone by the blood and the other fluids, the cause of all diseases, have fallen into as serious blunders as the determined solidists, who maintain that all diseases arise from a deranged condition of the solids, and that every change in the condition of the fluids in a consequence of that derangement. The believers in the humoral pathology have certainly gone too far; they have admitted that the animal fluids might be *acid*, *alkalescent*, or *acrimonious*, while we have no proof whatever that they ever do undergo such changes. The solidists have, likewise, gone much beyond the truth, in saying that every primitive change in the condition of the fluids is imaginary, and that the doctrine of humoral pathology is without foundation. Stahl relates* that the blood of a young woman, who was bled during a fit of epilepsy, was absolutely coagulated, as if that fluid had partaken in the rigidity affecting the muscular organs. Some authors say they have met with the same appearance; I have, however, never been able to discover any sensible difference between the blood of an epileptic patient and of any other person of the same constitution, of the same age, and living on the same regimen; and it should be considered, that to make a just comparison of our fluids, it is necessary that every thing should be alike in the persons from whom they are taken, with the exception of the difference of which we are to judge. In fact, the blood has not the same appearance, and does not coagulate in the same man-

* *Theoria Medica Vera*, p. 678.

ner, when taken from a child, a woman, or an old man; from a man who lives abstemiously, or from one who lives on a full diet.

After enumerating the changes which the blood undergoes, one might speak of those which affect the fluids that are formed from it, one might attend to the greenish, leek colour, and sometimes even darkish appearance of the bile, which is not always of the same degree of bitterness; the limpid state of the urine, which is voided colourless, without smell or flavour, after a fright, or during the convulsive fits of hysterical women; the fœtid smell and the viscidity of the saliva, when the salivary glands are under mercurial influence; the milky state of the serum which lubricates the parietes of the abdomen, and of the viscera which it contains after inflammation of the peritonæum; changes which almost universally depend on a derangement of action in the secretory organ, and sometimes, likewise, on the general condition of the fluids; for a gland cannot secrete a fluid endowed with the qualities which peculiarly belong to it, unless the blood furnish it with the materials of secretion, and unless it be in a state to bring about a due combination of their particles. When we come to the article of accidental secretions, we shall speak of some of those disorders of the fluids depending on a depraved condition of the secretory organs.*

XCIII. *Of the transfusion of blood.*—In the midst of the disputes to which the discovery of the circulation gave rise, some physicians conceived the idea of renovating completely the whole mass of the fluids in persons in whom they might be vitiated, by filling their vessels with the blood of an animal, or of a person in good health. Richard Lower, known by his work on the heart, first practised it on dogs, in 1665. Two years afterwards, transfusion was performed at Paris on men: it excited the greatest expectations: it was thought that by this process, called transfusive surgery (*chirurgie transfusiore*), all remedies would be superseded; that henceforth, to cure the most serious and inveterate diseases, it would be necessary merely to transfuse the blood of a strong and healthy man into the veins of the diseased; nay, they went so far as actually to imagine they might realise the fabulous fountain of *Jouvence;* they expected no less than to restore youthful vigour to the old, by infusing into them the blood of the young, and thus to perpetuate life. All these brilliant chimeras soon vanished; some underwent the experiment without any remarkable effects from it, others were affected with the most violent delirium; a lad of fifteen lost his senses, after suffering two months from the most violent fever. The legislative authority at last interfered, and prohibited those dangerous experiments.

The experiments on the subject of the transfusion of blood were repeated, but without success, at the Academy of Sciences. Perault opposed this new method, and shewed that it was very difficult for one animal to exist on the blood of another; that this fluid, though apparently the same in animals of the same age, was as different from it as the features of their face, their temper, &c.; that an extraneous fluid was thus introduced, which conveying to the organs an irritation to which they were not accustomed, must disorder their action in various ways; that if, as an objection to what he had said, they should bring forward what takes place in grafting, in which the sap of one tree nourishes another of a different kind, he would answer,—that vegetation does not depend on so complicated or on so delicate a mechanism as the nutrition of animals; that a hut may be formed of all kinds of stones taken at random, but that to build a palace stones must be designedly

* For additional remarks on the changes observed, under various circumstances, in the condition of the Blood, see APPENDIX, Note B B. —*J. C.*

shaped for the purpose, so that a stone destined for an arch will not do for a wall, or even for another arch.*

It would be easy, by means of a curved tube, to transfuse the arterial blood of an animal, from a wound in its carotid artery, into the saphena vein of a man, into the internal jugular, or into some of the cutaneous veins of the fore arm; but it is to be presumed, from experiments on living animals, that it would be very difficult to transfuse blood into the arteries,—as these vessels, filled with blood during life, do not yield to a greater distension. The capillaries, in which the arteries terminate, become corrugated, and refuse to transmit a fluid which does not act upon them according to their wonted sensibility. Such was the result of the experiments of Professor Buniva: he observed in a living calf, that the vessels did not transmit freely the fluid which was forced into them till the instant when the animal was killed, by dividing the upper part of the spinal marrow. Attempts have been made to turn to useful purposes these experiments on transfusion, by limiting the process to the injecting of medicinal substances into the veins. It is singular, that the moment a fluid is injected into the veins of an animal, it endeavours to perform motions of deglutition, as if the substance had been taken in at the mouth. All these attempts have been too few in number, and are not sufficiently authenticated, to justify their application to the human subject. But there is every reason to believe, that, even with the utmost care, the life of those who should submit to them would be endangered; so that it is at once humane and prudent to abstain from them.†

XCIV. *Of the secretions.*—It has been said in too general a way, that the organs receive from the blood conveyed to them by the arteries, the materials of the fluids which they separate from it. We have seen that the liver is a remarkable exception to this general rule.

One is, therefore, justified in saying that the elements of our fluids may be furnished by vessels of every kind, to the organs in which such fluids may be elaborated. The term *secretion*, whatever its etymology may be, denotes that function by which an organ separates from the blood the materials of a substance which does not exist in that fluid with its characteristic qualities. By the term secretion, one should not, therefore, understand the mere separation of a fluid existing before the action of the organ by which it is prepared.

XCV. *Of arterial exhalation.*—The differences between the secreted fluids are evidently connected with those of the organs employed in their formation. Thus, the arterial exhalation which takes place throughout the whole extent of the internal surfaces maintains their contiguity, throws out an albuminous serosity, which is merely the serum of the blood slightly changed by the feeble action of a very simple organisation. The analysis of the fluid of dropsy, which is merely the serosity constantly transuding from the surface of the serous membranes, as the pleura and peritonæum, shews, that it bears the strongest resemblance to the serum of the blood, and that it differs from it only in the varying proportions of albumen and of the different salts which it holds in solution.

This first kind of secretion, this perspiratory transudation, would seem to be a mere filtration, through the pores of the arteries, of a fluid already formed in the blood. There is, however, besides, an inherent action in the membranes whose surface it continually lubricates. If it were not for this action, the serum would remain united to the other constituent parts of the fluid, which is in too much motion, and at too high a temperature, to allow of a spontaneous separation. The term exhalation, which is applied to this secretion,

* Académie Royale des Sciences, p. 37.

† See APPENDIX. Note B B. for some remarks on transfusion, and on the injection of medicinal substances into the veins.—*J. C.*

gives an incorrect idea of it; for exhalation, which is a purely physical phenomenon, and requiring the presence of air to dissolve the fluid that is exhaling, cannot take place from surfaces that are in absolute contact, and between which there is no interval. The character of this mode of secretion is the absence of any intermediate substance between the vasa afferentia and the excretory ducts; the minute arteries and veins which enter into the structure of the membranes, being at once both the one and the other. The fluid secreted by the serous membranes, though bearing a considerable analogy to the serum of the blood, differs from it, however, by being animalized in a greater degree. The most important function of these organs is, therefore, that they concur in the common process of assimilation: the office, which has long been assigned to them, of facilitating the motion of the organs which they envelope, by lubricating their surface, will appear to be of very secondary importance, if it be considered, that respiration is not impeded by adhesions between the lungs and the pleura, and that, besides, the brain, which, when the cranium is whole, is completely motionless, is entirely surrounded by a serous membrane.

XCVI. *Of secretion from glandular follicles.*—Next in order to the serous transudation, which requires a very simple organisation, comes the secretion which takes place in the cryptæ, in the glandular follicles, and in the mucous lacunæ. Each of these small glands, contained within the membranes lining the digestive canal, the air tubes, and the urinary passages, and the collection of which forms the amygdalæ, the arytænoid glands, &c. may be compared to a small bottle, with a round bottom and a very short neck: the membranous parietes of these vesicular cryptæ receive a considerable number of vessels and nerves. The peculiar action of the parietes of these different parts determines the secretion of the mucus furnished by those glands. These mucous fluids, less liquid and more viscid than the serosity which is the product of the first mode of secretion, contain more albumen and a greater number of salts, differ still more from the serum of the blood, are more animalised, and are of a more excrementitious nature.

The bottom of these utricular glandulæ is turned towards the parts to which the mucous membranes adhere; and their mouth or neck opens on the free or unattached surface of those membranes. These kinds of excretory ducts, which are wider or narrower, and always very short, sometimes unite, run into each other, and open within the cavities. These common orifices, at which several mucous glands empty themselves, are easily seen on the amygdalæ, towards the mucous lacunæ of the rectum and of the urethra, at the base of the tongue, &c. The albuminous fluid, which is poured within those glandular cryptæ, remains some time within the cavity, and becomes thicker, from the absorption of its more fluid parts; for there are, likewise, lymphatics within the texture of their parietes. When the surfaces on which they are situated require to be moistened, this small pouch contracts and throws up the fluid with which it is filled. The secretion and excretion are promoted by the irritation which the presence of the air, of the aliment, or of the urine, occasions, by the compression exerted by those substances, and, lastly, by the peristaltic contractions of the muscular planes to which the mucous membranes adhere throughout the whole extent of the digestive tube.

XCVII. *Secretions of conglomerate glands.*—Those fluids which differ much from the blood, require for their secretion organs of a more complicated nature; such organs are called *conglomerate* glands, to distinguish them from the lymphatic glands, which have been termed *conglobate.* Those glands constitute the viscera, and are formed by a number of nerves and vessels of

all kinds, arranged in fasciculi, and united by cellular membrane. A membrane peculiar to the organs, or supplied by those which line the cavities in which they are contained, covers their outer part, and insulates them from the neighbouring organs.

The intimate arrangement of the different parts which form the secretory glands, the disposition of the arteries, of the veins and nerves, and the manner in which the lymphatic and excretory ducts arise from them, has given rise to endless discussions, and formed the basis of former physiological theories. What follows may be considered as a correct abstract of what is known on the subject.

The respective arrangement of the similar parts (*parties similaires**) which enter into the structure of the glands, and which form their proper substance, or parenchyma,† is different in each of them: this explains their differences in the double relation of their properties and their uses. The arteries are not, as Ruysch thought, immediately continuous with the excretory ducts, nor are there immediate glands between those vessels, as Malpighi conceived. It seems more probable that each gland has its own peculiar cellular or parenchymatous tissue, in the areolæ of which the arteries pour the materials of the fluid which the gland prepares, in virtue of a power which is inherent to it, and which is its distinguishing character. The lymphatics and the excretory ducts arise from the parietes of those cells, and these two kinds of vessels absorb; the one set, the secreted fluid, which they carry to the reservoirs in which it accumulates; while the other set take up that part of the fluid on which the organ has not completed its action—in other words, the residue of secretion.

XCVIII. *Of accidental secretions.*—If one wished to extend the idea attached to the term secretion, one might say that every thing in the living economy is performed by means of the secretions. What is digestion but the separation or secretion of the chylous or nutritive parts of aliments from their fæcal or excrementitious portion? Do not the absorbents concur in this secretion? May they not be considered as the excretory ducts of the digestive organs, which act on the aliment in the same manner as a secretory gland acts on the blood that contains the materials of the fluid to be elaborated? Respiration, as we have already seen, is but a double secretion which the lungs perform, on the one hand, of the oxygen contained in the atmospherical air; and, on the other hand, of the hydrogen and carbon, of the water, and of the other heterogeneous principles contained in venous blood; and, as will be shewn in the ensuing chapter, nutrition is but a peculiar mode of secretion, which is different in every organ. It is, therefore, only after a series of very delicate and very complicated separations and analyses, that the organs are enabled to make extraneous substances undergo such a change of composition as to render them fit for their growth and reparation.

There is every reason to believe, that the phenomena of sensation and of motion, by means of which man keeps up with surrounding objects the relations necessary to his existence, are the result of the secretions of which the blood furnishes the materials prepared by the brain, by the nerves, by the

* By *parties similaires*, the author means the simple elementary tissues. See the Preliminary Discourse.

† Do the different appearances of the substance of glandular bodies depend on the different manner in which the similar parts cross each other, and on their different proportions in each kind of gland? or do these differences of colour, of density, by means of which we so readily distinguish the substance of the liver from that of the salivary glands, depend on the existence of a peculiar tissue in each organ? This question cannot be answered in the present state of anatomy. The opinion, however, which supposes the different nature of the glands to depend on the different proportions of those constituent parts in each of them, appears the most probable.

muscles, &c. A plant separates from the earth, in which its roots are buried, the juices that it requires; these juices constitute the sap, which, after being filtered through a multitude of canals, supplies the different secretions, whose products are leaves, blossoms, and fruits, with gums, essential oils, and acids. All organised bodies are, therefore, so many laboratories, in which numerous instruments spontaneously perform various compositions, decompositions, syntheses, analyses, which may be considered as so many secretions from the common fluid.

If we confine ourselves in our view of the subject, and limit our attention to man, the principal and almost the sole object of our study, we shall see that the different secretions that may take place in him are extremely numerous and varied, and that a change in the condition of one of his organs is sufficient to enable it to secrete a new fluid. Hence inflammation in any gland is sufficient to alter the secretion of the organ that is affected. A portion of adipose tissue, on being affected with inflammation, shall secrete, instead of fat, a whitish fluid, known by the name of pus; the pituitary membrane, when inflamed, furnishes a mucus more fluid and more abundant, and which, by degrees, returns to its natural state, in proportion as the coryza goes off; the serous membranes, as the pleura and the peritonæum, will allow a greater quantity of serum of a more albuminous quality, sometimes even coagulable lymph, to exude. At other times, inflammation causes an adhesion of their contiguous surfaces, and as the inflammatory state varies in intensity, the accidental secretion will likewise vary as to its qualities; thus, the phlegmonous inflammation, which should furnish, on terminating in suppuration, a whitish fluid, thick, consistent, and almost without smell, will give out, if the process is not sufficiently active, a serous pus, colourless, and without consistence, &c. For the same reason, the blood-vessels of the uterus pour out in some women a dark-coloured blood, while in others they give out a mere serosity, very slightly, if at all, tinged with blood.

The menstrual discharge in women is the product of a real secretion of the arterial capillaries of the uterus, in the same manner as those vessels in the pituitary membrane, the membrane which lines the bronchia, the stomach, the intestines, the bladder, &c. pour out blood abundantly, or allow its transudation, when irritation is determined to those parts; as in hæmorrhage from the nose, in bleeding from the lungs, or from the stomach, when the vessels are not ruptured by external violence. Apoplexy itself, whether sanguineous or serous, may, in several instances, be ranked amongst those secretory evacuations, the quality of which varies according to the energy of the capillaries which produce it. On opening dead bodies, one frequently meets with a collection of blood in the ventricles of the brain in persons who have died from apoplexy; yet the most careful examination does not enable one to detect the slightest laceration or rupture in the veins, or in the arteries within the skull.

XCIX. *Of nervous influence on secretion.*—The nerves, of which there is always a certain number in the structure of the secretory organs, and which are principally branches of the great sympathetic* nerves, terminating in various ways in their substance, give to each of them a peculiar sensibility, by means of which they discover, in the blood which the vessels bring to them, the materials of the fluid they are destined to secrete, and these they appropriate to themselves by a real selection. Besides, the nerves communi-

* They are likewise given off in great numbers from the cerebral; thus, the salivary glands receive from the seventh pair, from the maxillary nerve, from the fifth pair, and from the cervical nerves, a number of nerves that will appear very great, if the bulk of those glands is considered.—*J. C*

cate to them a peculiar mode of activity, the exercise of which makes those separated elements undergo a peculiar composition, and bestows on the fluid which is the product of it, specific qualities, always bearing a certain relation to the mode of action of which it is the result. Thus, the liver seizes the materials of the bile contained in the blood of the vena portæ, elaborates, combines those materials, and converts them into bile,—an animal fluid, distinguishable by peculiar characteristic properties, subject to certain variations, according as the blood contains, in different proportions, the elements of which it is formed; and according as the gland is more or less disposed to retain them, and blend them together. The qualities of the bile, depending on a concurrence of all these circumstances, must present as many differences as the blood which contains its elements, and the liver, may present varieties, with regard to the composition of the former, and to the activity of the latter. Hence the many changes in the qualities of the fluid, the slightest of which, not affecting the health, escape observation; while those changes which are greater, and which disorder the natural order of the functions, shew themselves in diseases of which they may be considered as the effect, and at other times as the cause. These changes in the condition of the bile (and what is now said applies to almost all the secretions of the animal economy), are never carried so far as to make the bile lose all its distinguishing characters; it never takes on the qualities belonging to another fluid, it never resembles semen, urine, or saliva.

The secretory glands do not carry on an uninterrupted action; almost all of them are subject to alternate action and repose; all, as Bordeu observed, sleep or waken when irritation affects them or their neighbouring parts, and determines their immediate or sympathic action. Thus, the saliva is more plentifully secreted during mastication, and the gastric juice is poured within the stomach only while digestion is going on; when the stomach is emptied of food, the secretion ceases, and is renewed when the presence of food again excites a sufficient degree of irritation. The bile flows more abundantly, and the gall-bladder frees itself more readily of that which it contains, while the duodenum is filled by the chymous mass.

When a secretory organ is in action, it determines the motion of the parts in its vicinity, or, as Bordeu expresses it, within its atmosphere. A part is said to belong to the department of a certain gland, when it partakes in the motion affecting the latter during the process of secretion, or when it is employed in functions subservient to that of the gland: these departments are of different extent, according to the importance of the action of the gland. Thus, one may say that the spleen, and most of the viscera of the abdomen, are of the department of the liver, since they receive from it the blood on which they are to act. The liver is also comprised in the sphere of activity of the duodenum, since the distension of that intestine irritates it, and determines a more copious flow of its fluids, and a more abundant secretion of bile.

C. *Of the secretion of synovia, &c.*—The blood which is sent to a secretory gland, before reaching it, undergoes preparatory changes, which dispose it to furnish the materials of the fluid that is to be separated from it. We have seen, in treating of digestion, how the blood which the vena portæ sends to the liver is fitted for the secretion of bile. There can be no doubt that the portion of blood which is carried to the testicles, by the long, slender, and tortuous spermatic arteries, undergoes changes which bring it nearer to the seminal fluid.

The rapidity with which the blood flows into an organ, the length, the diameter, the direction, the angles of its vessels, the arrangement of their

extreme ramifications, which may be stellated, as in the liver—in fasciculi, as in the spleen—convoluted, as in the testicles, &c., are circumstances which should be taken into account in the study of each secretion, since all have some influence on the nature of the fluid secreted, and on the manner in which the secretion is effected.

The fluid which lubricates the whole extent of the movable surfaces by which the bones of the skeleton are articulated together, is not exclusively prepared by the membranous capsules which envelope the articulations. A number of reddish-coloured cellular substances, placed in their vicinity, co-operate in the secretion. Though these parts, which were long considered as synovial glands, do not completely resemble the conglomerate glands, and although no glandular bodies nor excretory ducts can be demonstrated in them, they cannot, however, but be considered as fulfilling, to a certain degree, the same functions; and one must admit that they are of some utility in the secretion of the synovia. They are always met with, and their extent and bulk are always proportioned to the extent of the auricular surfaces, and to the frequency of motion in the joints near which they are situated. They are found in all animals; pale and light coloured in those which have been long at rest; red, highly vascular, and bearing the marks of a kind of inflammatory diathesis, in those which have been compelled to violent exercise, as the oxen which are brought to Paris from distant provinces, and the wild animals which have been hunted. In anchylosis they are less red, and of greater consistence, than in a healthy state.

When, from the irritation attending friction, the fluids are determined towards an articulation which is in motion, do they not then, by passing through those glandulo-cellular bodies, undergo a peculiar modification, which renders them fitter for the secretion of synovia? This would not be the only instance in the human body of parts whose action is but secondary, and connected with that of other organs principally engaged in a secretion whose materials are contained in the blood which passes through them. It will be urged, no doubt, that this preparatory apparatus is not met with in the neighbourhood of the great cavities: but it should be recollected, that the chemical composition and the uses of the synovia are not precisely the same as those of the fluids secreted by the pleura or the peritonæum; and that, besides, the analogy between two objects does not constitute their identity. The human mind, being naturally indolent, loves to discover analogies that support it in its weakness, and that may save it the trouble of seeking points of difference. I am aware that, to prove that the mechanism of the synovial secretion, which exactly resembles that of the fluid which moistens the inside of the great cavities, and requires, like it, but a simple membranous apparatus, it is customary to repeat, in every possible way, that Nature is scanty in her means, and lavish in her results; that she produces from the same cause a variety of different effects, &c.; but, without pointing out the manifest absurdity of admitting metaphysical arguments in the natural sciences, is it not much more reasonable to acknowledge, with philosophers, that the primitive cause may vary in many ways, and that its innumerable modifications, whence arise the difference in the effects, exceed the limited powers of our understanding?

CI. *Of the state of the circulation and nervous influence in secreting parts.*—When a gland is irritated it becomes a centre of fluxion, towards which the fluids are determined from every part; it swells, hardens, contracts, is in a kind of state of erection, bends on itself, and acts on the blood conveyed by its vessels. Secretion, depending on the peculiar and inherent power of the glandular organ, is promoted by the slight motion which it receives from the

neighbouring muscles The gentle pressure of those parts on the glandular organs is sufficient to keep up their excitement, and to assist in the separation and excretion of the fluid. Bordeu, in his excellent work on the glands and on their action, has shewn that it is not in consequence of the compression which is produced on them by the neighbouring muscles, that they part with the fluid they have prepared ; and that physiologists were therefore very much in the wrong in saying that the excretion of a fluid consisted merely in its expression, and in comparing, under that point of view, the glands to sponges soaked with a fluid which they give out on being squeezed.

The excretory ducts of organs absorb or reject the secreted fluid according as it affects their inhalant mouths : these canals partake in the convulsive state of the gland, undergo a degree of erection, and contract on the fluid to expel it. Thus, the saliva starts from the parotid duct at the sight, or on the recollection, of food that has been longed for ; thus, the vesiculæ seminales and the urethra (for the reservoirs in which the fluids lie some time before being expelled may be considered as forming a part of the excretory ducts), contract, become straighter, and lengthen themselves, to force to a distance the spermatic fluid.

The thin and transparent ureters of fowls have been seen to contract on the urine, which, in these animals, concretes on the slightest stagnation.

After remaining a certain length of time in that state of excitement, the glands relax, their tissue collapses, the juices cease to be conveyed to it as plentifully, they fall into a state of repose or sleep, which restores their sensibility, exhausted by too much action. It it well known that a gland overstimulated, becomes, like any other part, insensible to the stimulus, the continued application of which parches and exhausts it.

From what has just been said relative to the mechanism of the secretions, it will be seen that this function may be divided into three very distinct periods ; 1st, that of irritation, characterised by the growth of the vital properties, and by the more copious accession of the fluids, the necessary consequence of that excitement ; 2dly, the action of the gland, that is, its secretion, properly so called ; 3d, and lastly, the action by which the organ parts with the fluid which it has prepared : this is the last process,—it is called excretion, and is promoted by the action of the neighbouring parts. The determination of fluids to the part, the secretion and excretion succeed each other ; they are preceded by the excitement, which is the primary cause of all the subsequent phenomena. The circulation is at first excited, more blood is sent into the part, and penetrates into the tissue of the gland. Dr. Murat has had occasion to open a considerable number of old men, who died at the Bicêtre, and who were known to be great smokers of tobacco. He uniformly observed that their parotid glands, continually called into action by that habit, were larger than in those who were not given to it, and that they were remarkably red, in consequence of the blood with which they were constantly injected.

What is the office of the nerves in the act of secretion ? what share has the nervous influence in the elaboration of the fluids furnished by the glandular organs ? All the glands which receive their nerves from the system of animal life, such as the lachrymal and salivary glands, appear, in certain cases, to receive from the brain the secretory excitation. The influence of the imagination is sufficient to determine it ; thus, we shed involuntary tears when the mind is taken up with painful thoughts ; and the mouth fills with saliva on the recollection of a grateful meal.* In such cases, the influence

* These glands, viz. the lachrymal and salivary, receive nerves both from the nearest ganglions and from the nerves of voluntary motion : the former set of nerves most probably enables

of the nerves on the process of secretion is indisputable; it is not so, however, with the conglomerate glands that receive their nerves from the great sympathetics. The secretion of the kidneys, of the liver, and of the pancreas, appears less influenced by affections of the mind; the brain, besides, has no immediate connexion with these glands; their nerves are almost entirely given off by the great sympathetics; the kidneys, in particular, receive no nerves from the brain or from the spinal marrow; hence the secretion of urine seems, more than any other, to be independent of the nervous influence.*

This great number of secretory organs, constantly engaged in separating various secretions from the mass of the fluids, would soon exhaust it, if the calculations of physiologists of the amount of what a gland is capable of secreting, were not manifestly exaggerated. In fact, if we admit with Haller, that the mucous glands of the intestinal canal secrete in twenty-four hours eight pounds of mucus; that, in the same space of time, the kidneys secrete four pounds of urine; that the same quantity is lost by the insensible perspiration, and again as much by the pulmonary exhalation; there will be lost, daily, twenty pounds of fluids, almost entirely excrementitious; for we do not include in that calculation the bile, the tears, nor the saliva and pancreatic fluid, which, in part, return into the blood after being separated from it; nor the serum, which moistens the internal surfaces, and which is purely recrementitious.

This exaggeration in the calculation of the fluids which are daily poured out by the different emunctories, is to be attributed to the circumstance of having taken the maximum of each secretion, without considering that they mutually supply each other; so that when less urine is voided, the quantity of perspiration is greater, and *vice versâ*. It is very well known, that a violent diarrhœa is frequently the consequence of sudden cold applied to the skin; the fluids, at once repelled towards the intestinal canal, having to pass through the mucous glands, whose action is greatly increased.†

CII. *Of other glands.*—It has been customary to enumerate among the glands certain bodies which have truly a glandular appearance, but the uses of which are yet unknown. Thus, the thyroid and thymus glands, which are parenchymatous organs, destitute of excretory ducts, though receiving

them to perform their ordinary functions, the latter excites or reinforces these functions whenever the mind is under certain impressions. —*J. C.*

* Although these organs are not directly influenced by the cerebral and spinal nerves, it cannot be satisfactorily denied that the ganglial nerves, which are so abundantly distributed to the blood-vessels supplying these organs, bestow on these vessels that peculiar influence which determines the nature and quantity of the secretion; for how can we suppose the capillary tubes, through which the blood flows, to be able to secrete a peculiar fluid of themselves, without resorting to the position that the nerves, which so abundantly supply the ramifications of the blood-vessels, and the substance of the secreting organs, actually influence, and, through the medium of those vessels, even produce, the secretions in question? Are not these nerves requisite to the vital actions of the viscera which they supply? Do we know an animal that does not possess them as a most essential part of its organisation? And can we suppose that they are distributed in so abundant a manner to the vessels of a secreting organ, without performing a most requisite part in the production of the fluids which that organ secretes? A close investigation of the structure of the secreting viscera and surfaces shews that their blood-vessels, which bear a close relation to the extent of function which such viscera individually perform, are more liberally supplied with this class of nerves than the vessels of any other of the animal textures: indeed, every important secreting gland has a distinct ganglion, or plexus of these nerves, surrounding the blood-vessels which belong to it, but more especially the arteries; and some of these organs have both a large plexus of nerves and a ganglion, whence their nerves are exclusively derived, and which appears to be entirely devoted to the functions of the viscus whose blood-vessels they so plentifully supply. See, on this subject, the APPENDIX, Notes H, A A, and those on Digestion —*J. C.*

† An increased flow of urine takes place in most persons during the first cold of autumn; and cold suddenly applied to the surface of the body, by checking the perspiration, often increases exhalation into the cellular textures and on the serous membranes, thus inducing dropsies.

many vessels and some nerves, do not appear to secrete any fluid. But may not the blood which is conveyed so plentifully to the thyroid gland, undergo, nevertheless, certain changes, though we may not be able to discover what they are? Besides, may not the lymphatics perform the office of excretory ducts, and convey back again immediately into the mass of the blood the fluid which has undergone changes in the glandular body? The capsulæ renales are in the same condition: they have, however, in addition, an internal reservoir, a kind of lacuna, whose parietes are smeared with a viscid and brown coloured substance secreted by the capsule, and which, doubtless, is conveyed into the mass of the blood by the lymphatics arising from the parietes of its internal cavity.

CIII. *Of the secretion of adeps within the cellular tissue.*—This soft tissue, which is diffused over the whole body, and affords a covering to all our organs, is of use not merely in separating them from one another, and in connecting together the different parts; it is, besides, the secretory organ of the adipose substance, a semi-concrete oily animal matter, which is found in almost every part of the body, deposited in its innumerable cells. The membranous parietes of these small cellular cavities are supplied by numerous minute arteries, in which the adeps is separated; it is conveyed by its specific light weight to the circumference of the column of blood in the vessels, and transudes through the pores in their parietes. Its quantity and consistence vary in different parts of the body, and in different persons: there is situated below the skin a thick layer of cellular substance (*pannicule grassieux*); it is found in considerable quantity between the interstices of the muscles, along the blood-vessels, near the articulations, and in the vicinity of certain organs, as the eyes, the kidneys, and the breasts. That which fills the bottom of the orbit, and which surrounds the eye-ball, is softish and almost fluid; that which envelopes the kidneys and the great joint, is, on the contrary, of the consistence of suet. Between these two extremes there are many gradations; and it may be said that the animal oil in question is not exactly the same in any two different parts of the body. The high temperature of the human body maintains it in a state of semi-fluidity, as may be observed in surgical operations.

In some parts it is even absolutely fluid; but its nature is then observed to be greatly changed, it no longer contains any oily substance, and differs but little from a mere aqueous gelatine. Thus, the fluid in the cellular tissue of the eye-lids, of the scrotum, &c., has been considered by several physiologists as positively different from fat. It may not be amiss to observe, that the laminæ of the cellular tissue in such circumstances yield more readily to extension, present a greater surface, form membranous expansions, and circumscribe cells of a considerable size, so that the differences in the secretion perfectly coincide with the difference of structure. It may further be observed, that the functions of the eye-lids and of the penis required that they should not contain any fat. Considerable deformity, when the person grew fat, would have been the consequence of the increased bulk of these parts; and besides, the folds of the skin would not have that free motion which their functions require. No real adeps is ever found within the skull, and the utility of this condition is very obvious. To how many dangers would not life have been exposed, if a fluid so varying in quantity, and the amount of which may be trebled in a very short space of time, had been deposited in a cavity accurately filled by an organ which is affected by the slightest compression?

In an adult male, of moderate *embonpoint*, the proportion of adeps is about one-twentieth of the weight of the whole body; it is greater in pro-

portion in children and in females, for its quantity is always relative to the energy of the functions of assimilation. When digestion and absorption are performed with great activity, fat accumulates within the cellular substance: and if it be considered that it is but imperfectly animalised; that it bears the most striking analogy to the oils extracted from plants; that it contains very little azote and much hydrogen and carbon, like all other oily substances, since, on distillation, it is decomposed, and yields water and carbonic acid, with a very small quantity of ammonia; that its proportions are very variable, and may be considerably increased or diminished, without manifestly impairing the order of the functions; that animals that spend a great part of their life without eating, seem to exist during their torpid state on the fat which they have previously accumulated in certain parts of the body;*—one will be led to think that the state of fat is to a portion of the nutritive matter, extracted from the food, a kind of intermediate state through which it has to pass before it can be assimilated to the animal whose waste it is destined to repair. Animals that live on grain and vegetables are always fatter than those which live exclusively on flesh. Their fat is consistent and firm, while that of carnivorous animals is almost completely fluid.

A corpulent man on having his diet suddenly reduced, sensibly becomes thinner in a very short time; the bulk and weight of his body diminishes from the absorption of the fat which supplies the deficient quantity of blood. Adeps may, therefore, be considered as a substance in reserve, by means of which, notwithstanding the small quantity of food and its want of nutritious qualities, Nature finds wherewith to repair the daily waste.

CIV. *Of the use of the fat.*—The use of adeps is not, as has been stated, on the authority of Macquer, to absorb the acids that are formed in the animal economy; that which is obtained from it by distillation (*the sebaceous acid*) is a new product, formed by the combination of the oxygen of the atmosphere with the hydrogen, the carbon, and the small quantity of azote which it contains. The small quantity of this last substance nearly constitutes it a vegetable acid. Fat has a considerable affinity for oxygen, and by combining with it turns rancid, after remaining some time exposed to the air. It deprives metallic oxides of a part of their oxygen, and likewise, on being triturated with metallic substances, promotes their oxidisement. In proportion as it absorbs oxygen its density increases; thus, oils become concrete by combining with oxygen, and fat acquires a consistence almost equal to that of wax, which is itself a fatty substance highly oxidised.

Besides the principal use we have assigned to adeps, and according to which the cellular system may be looked upon as a vast reservoir, in which there is deposited a considerable quantity of nutritive and semi-animalised matter, this fluid answers several purposes of secondary utility. It preserves the body in its natural temperature, being, as well as the tissue of the cells in which it is contained, a very bad conductor of heat. Persons who are excessively corpulent, scarcely feel the most severe cold; and the animals which inhabit northern climates, besides being clothed in a thick fur, are likewise provided with a considerable quantity of fat. The fishes of the frozen seas, the animals which seldom go far from the polar regions, and all kinds of whales, are covered with fat, and have also a considerable quantity within their bodies. By its unctuous qualities, fat promotes muscular contraction,

* Marmots and dormice become prodigiously fat during the autumn; they then take to their holes, and live in them during the six winter months on the fat which is accumulated in all their organs. There is most fat collected in the abdomen, in which the epiploon forms masses of a considerable size. When, in the spring, their torpor ceases, and they awaken from their sleep, they are, for the most part, exceedingly emaciated.

the motion of the different organs, and the free motion on each other of the different surfaces; it stretches and supports the skin, fills vacuities, and gives to our limbs those rounded outlines, those elegant and graceful forms, peculiar to the female body. Lastly, it envelopes and covers over the extremities of the nerves, diminishes their susceptibility, which is always in an inverse ratio of the *embonpoint*,—a circumstance that induced a physician of merit to say, that the nervous tree, planted in the adipose and cellular substance, suffers when, from the collapse and removal of that tissue, its branches are exposed in an unprotected state to the action of external causes, as injurious to them as the rays of the sun to a plant torn from its native soil. It is, in fact, observed, that nervous people are exceedingly thin, and have an excessive degree of sensibility. Too much fat, however, is as injurious as too small a quantity of it. I have seen several persons whose obesity was such that, besides being completely incapable of taking the slightest exercise, they were in great danger of suffocation. Respiration in such persons is, at times, interrupted by deep sighs; and their heart, probably overloaded with fat, expels with difficulty the blood within its cavities.

CV.—According to modern chemists the use of fat is to take from the system a part of its hydrogen. When the lungs or liver are diseased, when respiration or the biliary secretion does not carry out of the system a sufficient quantity of that oily and inflammable principle, fat forms in a greater proportion. They appeal to the result of the experiment of shutting up a goose, whose liver is to be fattened, in a confined cage, placed in a hot and dark situation, and in gorging it with paste, of which it eats the more greedily, as being unable to stir, it gratifies its inclination to action by exerting the organs of digestion. Notwithstanding this quantity of food, the bird becomes emaciated, is affected with a kind of marasmus, its liver softens, grows fatter, more oily, and attains an enormous size.

This experiment, and many other facts, prove that the secretions from which analogous products are formed, may mutually supply each other: but can we admit the chemical theory of the use of fat, when we recollect, that frequently, in the most corpulent persons, respiration and the secretion of the bile are performed with great freedom and with no difficulty; while the difficult respiration attending pulmonary consumption, and the difficult flow of the bile from an obstruction of the liver, are always accompanied with complete marasmus?

Whatever moderates the activity of the circulatory system, tends to bring on adipose plethora. Thus, an inactive state of the mind and body, profuse bleedings, castration, sometimes induce obesity; an affection in which the cellular tissue appears affected with atony, and undergoes an actual adipose infiltration, somewhat analogous to that which gives rise to tumours called steatomatous. If the energy of the heart and arteries is too great, emaciation is always the consequence; when, on the contrary, the sanguineous system is languid, there is formed a gelatinous fat, and the *embonpoint* is a mere state of bloatedness.

This incompletely formed fluid, which distends the parts in persons of a leucophlegmatic habit, is but an imperfect kind of fat; it resembles the marrow or the medullary juice, which is a very liquid fat, whose consistence diminishes when animals become lean. Enclosed within the cells of the osseous tissue, in cavities whose sides cannot collapse, and whose dimensions must always remain the same, the marrow, of which they are never free, is of different degrees of density; and what authors say of its diminished quantity, must be understood as applying to the diminution of its consistence.

CVI. *Of the secretion of the marrow.*—The secretion of the marrow is, like

that of the fat, a mere arterial transudation: it is performed by the medullary membrane, which is thin, transparent, and cellular, lines the inside of the central cavity of the long bones, and extends over all the cells of that spongy substance. The medullary membrane, when in a healthy state, does not give any marks of relative sensibility. In all the amputations I have performed, and they have not been few, in all the operations of the same kind at which I have been present, whatever the bone was, whether it was divided near a joint or in the middle of its body, I never knew the patient complain of pain, provided the limb was well supported by the assistants, and provided no jerk was given by the operator himself. In that operation, the pain occasioned by the division of the skin and of the nerves overcomes every other pain; and I have always seen patients, impressed with the popular prejudice, and expecting anxiously the division of the bone, feel quite free from pain as soon as the saw had begun to work. Nay, several, after expressing by their cries the most acute pain, taking advantage of the kind of ease which follows the division of the flesh, raise their head, and look on while the bone is being sawn through; at once actors and spectators in this last part of a painful and bloody operation.

Yet the medullary membrane, the injury of which is attended with no pain while in a healthy state, becomes the seat of the most exquisite sensibility in the pains in the bones which mark the last stages of the venereal disease; in the kind of conversion into flesh of the solid bone, known by the name of spina ventosa, as will be mentioned in speaking of the uses of the marrow, in the chapter on the Organs of Motion and on their Action.*

CHAPTER VI.

OF NUTRITION.

CVII. Nutrition the end of the assimilating Processes.—CVIII. and CIX. Of the Process of Nutrition.—CX. Substances capable of yielding Nutriment.—CXI. Changes produced in alimentary Substances.—CXII. The ultimate result.

CVII.—All the functions which we have hitherto made the object of our study,—digestion, by which the alimentary substances received within the body are deprived of their nutritive parts; absorption, which conveys that recrementitious extract into the mass of the fluids; the circulation, by which it is carried to the parts wherein it is to undergo different changes;—digestion, circulation, absorption, respiration, and the secretions, are but preliminary acts, preparatory to the more essential function treated of in this chapter, and the consideration of which terminates the history of the phenomena of assimilation.

Nutrition may be considered as the complement of the functions of assimilation. The aliment, altered in its qualities by a series of decompositions, animalised, and rendered similar to the substance of the being which it is to nourish, is applied to the organs whose waste it is to repair; and this identification of the nutritive matter to our organs, which take it up and appropriate it to themselves, constitutes nutrition. Thus there is accomplished a real conversion of the aliment into our own substance.

* For some further remarks on Secretion, see Appendix, Note C C.—*J. C.*

There is incessantly going on a waste of the integrant particles of the living body, which a multiplicity of circumstances tend to carry away from it: several of its organs are constantly engaged in separating from it the fluids containing the recrementitious materials of its substance, worn by the combined action of the air and of caloric, by inward friction, and by a pulsatory motion that detaches its particles.

Analogous, therefore, to the vessel of the Argonauts, so often repaired in the course of a long and perilous navigation, that on her return no part of her former materials remained, an animal is incessantly undergoing decay, and if examined at two different periods of its duration, does not contain one of the same molecules. The experiment performed with madder, which dyes red the bones of animals among whose food it is mixed, proves, most unquestionably, this incessant decomposition of animated and living matter. One has only to interrupt, for a sufficient length of time, the use of that plant, to make the uniformly red colour assumed by the bones completely disappear. Now, if the hardest and most solid parts, which are best calculated to resist decay, are undergoing a perpetual motion of decomposition and of regeneration, there can be no doubt that this motion must be far more rapid in those whose power of cohesion is much inferior—for example, in the fluids.

Attempts have been made to determine the period at which the body is completely renovated; it has been said, that an interval of seven years was required for one set of molecules to disappear and be replaced by others; but this change must go on more rapidly in childhood and in youth. It must be slower at a mature age, and must require a considerable time at a very advanced period of life, when all the parts of the body become, in a remarkable degree, fixed and firm in their consistence, while the vital powers become more languid. There can be no doubt, that the sex, the habit, the climate in which we live, the profession we follow, our mode of life, and a variety of other circumstances, accelerate or retard it; so that it is impossible to fix, with any degree of certainty, its absolute duration.

CVIII. *Of the process of nutrition.*—The parts of our body, in proportion as they undergo decay, are repaired only by means of homogeneous particles exactly like themselves; were it otherwise, their nature, which always remains the same, would be undergoing perpetual changes.

When, in consequence of the successive changes which it has undergone from the action of the organs of digestion, of absorption, of the circulation, of respiration, and of secretion, the nutritive matter is animalised or assimilated to the body which it is to nourish, the parts which it moistens retain it and incorporate it to their own substance. This nutritive identification is not performed alike in the brain, in the muscles, in the bones, &c. Each of them appropriates to itself, by a real process of secretion, whatever it meets with fitted for its nature in the fluids conveyed to it by the different kinds of vessels, but especially by the arteries; it leaves unaffected the remaining heterogeneous particles. A bone is a secretory organ, around which phosphate of lime is deposited; the lymphatic vessels which, in the process of nutrition, perform the office of excretory ducts, remove that saline substance, when it has lain sufficiently long in the cells of its tissue. The same happens to the muscles with regard to fibrina, and to albumen with regard to the brain; every part appropriates to itself, and converts into a solid form, those fluids which are of the same nature, in virtue of a power of which the term affinity of aggregation, used in chemistry, gives an idea, and of which it is perhaps the emblem.*.

* Assimilation takes place in a more perfect manner when the vital influence is complete in all its relations. See APPENDIX, Note D D.—*J. C.*

The nutrition of a part requires that it should be possessed of sensibility and motion ; by tying the arteries and nerves of a part, it cannot be nourished, nor can it live. The blood which flows along the veins, the fluid conveyed by the absorbents, contain, in a smaller proportion than arterial blood, vivifying and reparatory particles. It is even commonly thought, that the lymph and venous blood contain no directly nutritive particles. As to the share which the nerves take in the process of nutrition, that is not yet completely determined. A limb that is paralysed, by the division or tying of its nerves, or by any other affection, sometimes retains its original size and plumpness ;* most frequently, however, though perhaps for want of motion, it becomes parched, emaciated, and shrinks in a remarkable degree.

CIX.—We should be enabled to understand the process of nutrition, if, after having accurately determined the difference of composition between our food and the substance itself of our organs, we could see how each function robs the aliments of their qualities, to assimilate them to our own bodies ; and what share each function takes in the transmutation of the nutritive particles into our own substance. To illustrate this point, suppose a man to live exclusively on vegetable substances, which, in fact, form the basis of our food : on whatever part of the plant he may live, whether on the stem, on the leaves, on the blossoms, on the seeds, or on the root, carbon, hydrogen, and oxygen, enter into the composition of these vegetable substances, which, by a complete analysis, may all be resolved into water and carbonic acid. To these three constituent principles there is frequently united a small quantity of azote, of salts, and of other materials, in different proportions. If, then, we examine the nature of the organs in this man, whose food is entirely vegetable, it will be found that they are different in their composition, and far more animalised than that kind of food ; that azote predominates, though the vegetable substance contains none or only a very small quantity ; that new products, undistinguishable in the aliments, exist in considerable quantity in the body which is fed on them, and appear produced by the very act of nutrition.

The essence of this function is, therefore, to make the nutritive matter undergo a more advanced state of composition, to deprive it of a portion of its carbon and of its hydrogen, to make azote predominate, and to produce several substances which did not exist in it before. All living bodies seem to possess the faculty of composing and decomposing the substances by means of which they are maintained, and to form new products ; but they possess it in various degrees of energy. The sea-weed, from the ashes of which soda is obtained, on being sown in a box of soil in which there is not a single particle of that alkali, and watered with distilled water, will no longer contain it, as if it had grown on the sea shore, in the midst of marshes constantly inundated by salt and brackish water.†

Living bodies, then, are real laboratories, in which there are carried on

* This and various other considerations evince that nutrition is not essentially dependent upon the voluntary nerves, but upon that class of nerves (the ganglial), which is chiefly ramified on the blood-vessels. See the above Note in the APPENDIX.—*J. C.*

† I am unacquainted with the details of the experiment referred to by the author ; he quotes it, I conceive, to shew that the power which, he says, is common to all living bodies, of producing a substance not supplied to them from without, is not possessed, in the same degree, by all bodies endowed with life ; since the sea-weed here alluded to does not possess it in an equal degree when watered with distilled as with sea-water. This, I apprehend, is the author's meaning, though the text is somewhat obscure, and would almost lead one to believe he meant, that no alkali whatever can be obtained from the sea plant under the circumstances he states : "L'algue marine, dont les cendres fournissent la soude, semée dans une caisse pleine d'un terreau qui ne contient pas un seul atome de cet alkali, arrosée avec l'eau distillée, *ne le fournit plus*, comme si elle avoit pris sa croissance au milieu des marais toujours inondés par leurs eaux saumâtres et muriatiques."—*T.*

combinations and decompositions which art cannot imitate; bodies that appear to us simple, as soda and silex, seem to be formed by the union of their constituent particles; while other bodies, whose composition we do not understand, undergo an irresistible decomposition: hence, methinks, one may infer, that the power of nature in the composition and decomposition of bodies far exceeds that of chemistry.

Straw and *cereal* plants contain a considerable quantity of silex, even when the earth in which they grow has been carefully deprived of its silicious particles. Oats, particularly, contain a large quantity of that vitrifiable earth; the ashes obtained by burning its seed, on being analysed by means of the nitric acid, were found by M. Vauquelin to contain $\frac{607}{1000}$ of pure silex indissoluble in that acid, and 0·393 of phosphate of lime dissolved in it.

The excrements of a hen fed for ten days on oats only, on being calcined and analysed by the same chemist, produced twice as much phosphate and carbonate of lime as was contained in the oats, with a small deficiency in the quantity of silex, which might have been employed in furnishing the excess of calcareous matter; a transmutation depending on the absorption of an unknown principle, to the amount of nearly five times its own weight.*

CX. *Substances capable of yielding nutriment.*—A substance, to be fit for our nourishment, should be capable of decomposition and fermentation; that is, capable of undergoing an inward and spontaneous change, so that its elements and relations may be altered. This spontaneous susceptibility of decomposition excludes from the class of aliments whatever is not organised and is not a part of a living body; thus, mineral substances absolutely resist the action of our organs, and are not convertible into their own substance. The common principle extracted from alimentary substances, however varied they may be, the *aliment*, as Hippocrates terms it, is, most probably, a compound highly subject to decomposition and fermentation; this is likewise the opinion of all those who have endeavoured to determine its nature. Lorry thinks it a mucous substance; Cullen says it is saccharine; Professor Hallé considers it as an hydro-carbonous oxide, which differs from the oxalic acid only in containing a smaller quantity of oxygen. It is evident that these three opinions are very much alike, since oxygen, carbon, and hydrogen, combined in different proportions, form the mucous saccharine substances and the base of the oxalic acid. On analysing the animal substance, by means of the nitric acid, it is reduced to this last base by depriving it of a considerable quantity of azote, which constitutes its most remarkable character.

But whence comes this enormous quantity of azote? How happens it that the flesh of a man living exclusively on vegetables contains as much azote and ammonia, and is as putrescent, as that of a man living on animal food? Respiration does not introduce a single particle of azote into our fluids: this gas comes out of the lungs as it entered; the oxygen alone is diminished in quantity.† Might not one suspect that this element of animal substances is a product of the vital action, and that, instead of receiving it from our aliments, we form it within ourselves, by an act that is *hypher-chemical*, that is, which chemistry cannot imitate?‡

* See the *Annales de Chimie*, and the *Système des Connaissances Chimiques* de Fourcroy, tom. x. p. 72.

† See Appendix, Notes W and D D.

‡ The experiments of Messrs. Allen and Pepys prove, that when an animal is made to breathe pure oxygen, the blood disengages a certain quantity of azote, and absorbs an equal quantity of oxygen.—*Philosophical Transactions*, 1809. But this arises from the azote already absorbed by the blood from the air; for the recent experiments of M. Edwards demonstrate that azote is absorbed by the blood in the lungs, and thence given out during respiration. See *Les Agens Physiques sur la Vie*, par M. Edwards, 1824.—*J. C.*

CXI. *Changes produced in alimentary substances.*—It has been maintained, that the hydro-carbonous oxide combines, in the stomach and intestinal canal, with oxygen, whether this principle has entered with the aliments into the digestive tube, or whether it is furnished by the decomposition of the fluids within that cavity. The intestinal fluids extricate azote, which combines with the alimentary mass, and occupies the place of the carbon, which the oxygen has taken from it, to form carbonic acid. On reaching the lungs, and being again exposed to the action of the oxygen of the atmosphere, this gas robs it of a portion of its carbon, and as it disengages the azote of the venous blood, it brings about a new combination of that principle with the chyle. Lastly, propelled with the blood to the surface of the skin, the atmospherical oxygen disengages its carbon and completes its *azotisation*. The cutaneous organ is perhaps to the lymphatic system, what the pulmonary organ is to the sanguineous system.

The animalisation of the animal substance is therefore effected principally by the loss of its carbon, which is replaced by the excess of azote in the animal fluids. These maintain themselves, in this manner, in a due temperament; for, continually parting with the carbonous principle in the intestinal, pulmonary, and cutaneous combinations, they would be over-animalised, if an additional quantity of chyle did not seize the azote, which is in excess. Still, this theory does not account for the formation of the phosphoric salts, of the adipocire, and a variety of other products: but, without adopting it to the full, one may presume, from the experiments and facts on which it rests, that the oxygen of the atmospherical air is one of the most powerful agents employed by nature in the transformation of the aliments we live upon into our substance.

How are those animals nourished which live solely on mere animalised flesh; that is, containing a greater quantity of azote, and a greater proportion of ammonia, than their own substance? In such a case, the assimilation of the aliments consists in their *disanimalisation*, either by the co-operation of all the organs, or by the sole action of the digestive organs, by the combination of the gastric juice with the other fluids.

The constituent elements entering into the composition of our organs, whether coming from the exterior, or formed by the vital power itself, are thrown out of our body by the different emunctories, and cease to form a part of it, after remaining within it for a limited time. The urine carries along with it an enormous quantity of azote; the lungs and the liver rid us of the carbon and of the hydrogen; the oxygen, of which eighty-five parts in the hundred enter into the composition of water, is evacuated by means of the aqueous secretions, which carry off, in a state of solution, the saline and other soluble principles.

Among those salts there is one but little soluble, and which, nevertheless, is of primary consequence among the constituent principles of the animal economy. Phosphate of lime, in fact, forms the base of several organs; it almost entirely forms the osseous system at an advanced period of life; all the white organs, all our fluids, contain a remarkable quantity of that substance, of which the economy rids itself by a kind of *dry* secretion. The outer covering is, in all animals, the emunctory destined for that purpose: the annual moulting of birds, the fall of the hair of quadrupeds, the renovation of the scales of fishes and reptiles, carry off every year a considerable quantity of calcareous phosphate. Man is subject to the same laws, with this difference, that the annual desquamation of the epidermis is not under the absolute influence of the seasons, as in the brute creation. The human epidermis is renewed annually, as well as the hair on the head and on the body;

but this change is brought about gradually, and is not completed in a season: it does not take place in the spring, as in most animals, nor in autumn with the fall of the leaf, though at these two periods the hair falls off in greatest quantity, and the desquamation of the cuticule is most active. These two phenomena last throughout the whole year, as in southern climates the fall of the leaves and the renovation of vegetation are continually going on. As will be mentioned, in speaking of the functions of generation, man living in a state of society, and enjoying all the advantages of civilisation, is not as much under the influence of the seasons as the inferior animals. One cannot, however, but observe, that the successive shedding and renewing of the epidermoid parts, as the cuticle, the nails, and the hair, are among the most effective means which nature possesses of parting with the phosphate of lime, so abundant in all animals, and which, nevertheless, is so insoluble, and consequently so unfit to be carried out of the system along with the excrementitious fluids. This effect is very remarkable, on the termination of several diseases, in the salutary renovation of the solids and fluids which takes place during convalescence. The hair ceases to grow on the bald head of an old man; his perspiration diminishes. May not this be the cause of the great quantity of calcareous salts, of the ossification of the vessels, of the induration of the membranes?

CXII. What is the ultimate result presented to us by this series of functions, linked together, growing out of one another, and all acting on the matter of nutrition, from the moment it is received within the body, till it is applied to the growth and reparation of its organs?* It shews us man living within himself, unremittingly employed in converting into his own substance heterogeneous substances, and reduced to an existence purely vegetative, inferior even to the greater part of organised beings in his powers of assimilation. But how high is he not placed above them all in the exercise of those functions we are now about to contemplate,—functions which raise him above his own nature, which enlarge the sphere of his existence, which serve him to provide for all his wants, and to keep up, with all nature, those manifold relations which subject her to his empire!†

* Intimately connected with the consideration of nutrition is that of reproduction. This phenomenon takes place to a very limited extent indeed in the more perfect animals; but as we descend in the scale of creation, we find that the destruction of a member or part of the body of an animal is, after a time, followed by a partial or entire reproduction of the part destroyed; and amongst the lowest class of animals, even a portion only of the body becomes a perfect animal, and presents the specific characters of the parent. In this respect, the phenomena of animal life, as we descend through its gradations, approach those of vegetable existence.

† For further observations on *Nutrition*, see APPENDIX, Notes S and C C.

Second Order.

FUNCTIONS WHICH TEND TO THE PRESERVATION OF THE INDIVIDUAL, BY ESTABLISHING HIS RELATIONS WITH THE BEINGS THAT SURROUND HIM.

CHAPTER VII.

OF SENSATIONS.

CXIII. Man enjoys the existence of Sensation in its greatest perfection.—CXIV. Of Light.—CXV. Sense of Sight.—CXVI. Of the Eye-brows, Eye-lids, and Lachrymal Apparatus.—CXVII. Of the Globe of the Eye, &c.—CXVIII. Mechanism and Phenomena of Vision.—CXIX. Of the Organ of Light in the lower Animals.—CXX. Of Sound.—CXXI. Of the Organ and Mechanism of Hearing.—CXXII. Pathological Physiology of Hearing.—CXXIII. Of Odours.—CXXIV. Of the Organ of Smell.—CXXV. Of the Sensation of Odours.—CXXVI. Of Flavours.—CXXVII. and CXXVIII. Of the Sense of Taste.—CXXIX. Of the Sense of Touch.—CXXX. Of the Integuments.—CXXXI. Of the Nails.—CXXXII. and CXXXIII. Of the Hair of the Head and of other parts.—CXXXIV. and CXXXV. Of the Sensations conveyed by Touch, and of its States in different parts of the Body.—CXXXVI. Of the Nerves.—CXXXVII. Structure of Nerves.—CXXXVIII. and CXXXIX. Distribution of Nerves.—CXL. Of the Spinal Chord and its Functions.—CXLI. Of the Coverings of the Brain.—CXLII. Of the Size of the Brain.—CXLIII. Structure of the Cerebral Mass.—CXLIV. The Circulation of the Brain.—CXLV. The Connexion between the Actions of the Brain and Heart.—CXLVI. Of the Theory of Syncope.—CXLVII. to CL. Of the Motions of the Brain.—CLI. Functions of the Brain and Nerves.—CLII. Analysis of the Understanding.—CLIII. Sources of our Ideas.—CLIV. Of Perception, Attention, Memory, Imagination, and Reasoning.—CLV. Of spoken Signs or Words.—CLVI. to CLVIII. Of the Disorders of Thought.—CLIX. Of Sleep and Waking.—CLX. Of Dreams and Somnambulism.

CXIII.—We have already seen how the human body, essentially changeable and perishable, maintains itself in its natural economy, carries on its growth, and supplies its decay, by assimilating to its own substance principles that are yielded to it by the food it digests, and by the air it breathes. I shall now proceed to examine by what organs man is enabled to keep up, with all nature, the relations on which his existence depends; by what means he is made aware of the presence of objects which concern him, what means he possesses to fit his connexion with them to his welfare, to draw them towards him or to repel them, to approach or to avoid and escape them, as he perceives in them danger, or the promise of enjoyment.

Man possesses, in all its plenitude, this new mode of existence, which is denied to vegetable nature. Of all animals, it is he that receives impressions the most crowded and various, that is most filled with sensations, and that employs them with the most powerful combination, as the materials of thought, and the sources of intelligence; he is the best organised for feeling the action of all beings around him, and re-acting on them in his turn. In the study which we are about to undertake, we shall see many instruments placed on the limits of existence, on the surface of the living being ready to receive every impression; conductors, stretching from these instruments to one common centre, to which all is carried; conductors through which this central organ regulates the actions, which now transport the whole body from one place to another (*locomotion*); now merely change the relative

situation of its parts (*partial motion*) ; and at other times produce in the organs certain dispositions, of which speech and language, in their various forms, are the result.

If we are thoroughly to understand the mechanism of this action of outward objects on our body, we must follow the natural succession of the phenomena of sensation ; studying first the bodies which produce the sensitive impression, examining next the organs that receive it, and next the conductors which transmit it to a particular centre, whose office is perception. To take the sense of sight, for instance, we can never understand how it is that light procures us the knowledge of certain qualities of bodies, if we have not learnt the laws to which that fluid was subjected, if we know nothing of the conformation of the eyes, of the nerves by which those organs communicate with the brain, and of the brain itself, whither all sensations, or rather the motions in which they consist, are ultimately carried.

CXIV. *Of light.*—At this day, the greater part of natural philosophers consider it as a fluid impalpable, from its exceeding tenuity. Many believe it to be only a modification of caloric, or of the matter of heat ; and this last opinion has received much plausibility from the late observations of Herschel.* I shall not examine whether, as Descartes and his followers imagine, light, consisting of globular molecules, exists of itself, uniformly diffused through space ; or as Newton has taught us to believe, it be but an emanation of the sun and fixed stars, which throw off from their whole surface a part of their substance, without ever exhausting themselves by this continual efflux ; it is enough for us to know, 1st, That the rays of this fluid move with such velocity, that light passes in a second through a distance of seventy two thousand leagues, since, according to the calculation of Roëmer, and the tables of Cassini, it traverses in something less than eight minutes the thirty-three millions of leagues that separate us from the sun ; 2dly, That light is called *direct*, when it passes from the luminous body to the eye without meeting any obstacle ; *reflected*, when it is thrown back to that organ by an opaque body ; *refracted*, when its direction has been changed by passing from one transparent medium to another of different density. 3dly, That the rays of light are reflected at an angle equal to that of incidence ; that a ray passing through a transparent body, is more strongly refracted as the body is more convex on the surface, denser, or of more combustible elements. It was from this last observation, that Newton conjectured the combustibility of the diamond, and the existence of a combustible principle in water, since placed beyond doubt, by the beautiful experiments of modern chemistry. 4thly, That a ray of light refracted by a glass prism, is decomposed into seven rays, red, orange, yellow, green, blue, indigo, and violet. Each of these rays is less refrangible as it is nearer to the red. This ray is, of all, that which strikes the eye with the greatest force, and produces on the retina the liveliest impressions. The eagerness of savages for stuffs of this colour is well known. Among almost all nations it has dyed the mantle of kings : it is the most brilliant and splendid of all : there are animals whose eyes seem scarcely to sustain it : I have seen maniacs whose madness, after a long suspension, never failed to break out at the sight of a red cloth, or of one clothed in that colour. Green is,

* This celebrated astronomer has published in the Philosophical Transactions of the Royal Society for 1800, a series of experiments, which shew that the different coloured rays heat in different degrees the bodies on which they fall, and that the red ray, which is the least refrangible, gives also the greatest heat.

The thermometer placed out of the spectrum and towards the red ray, so that it would receive any rays yet less refrangible, rises higher than when it is placed in that colour : from which Herschel concludes that rays are given out by the sun, too little refrangible to produce the sensation of light, and of colours, but which produce the sensation of heat.

on the contrary, the softest of colours, the most permanently grateful, that which least fatigues the eyes, and on which they will longest and most willingly repose. Accordingly, nature has been profuse of green, in the colouring of all plants; she has dyed, in some sort, of this colour the greater part of the surface of the globe. When the eyes bear uneasily the glare of too strong a light, glasses of this colour are used to soften the impression, which slightly tinge with their own hue all the objects seen through them. 5thly, The violet ray, last in the scale, of which the middle place is filled by the green, is of all the weakest, the most refrangible. Of all colours, violet has the least lustre; forms shew to less advantage under it, their prominences are lost; painters accordingly make but little use of it. When an enlightened body reflects all the rays, the sensations they might separately produce blend into the sensation of white; if it reflects a few, it appears differently coloured according to the rays it repels: finally, if all be absorbed, the sensation of black is produced, which is merely the negation of all colour. A black body is wrapped in utter darkness, and is visible only by the lustre of those that surround it. Lastly, That from every point in the surface of a luminous or enlightened body there issue a multitude of rays, diverging according to their distance, with a proportionate diminution of their effect; so that the rays from each visible point of the body form a cone, of which the summit is at that point, and the base the surface, of the eye on which they fall.

CXV. *Sense of sight.*—The eyes, the seat of this sense, are so placed as to command a great extent of objects at once, and enclosed in two osseous cavities, known by the name of orbits. The base of these cavities is forwards, and shaped obliquely outwards; so that their outward side not being so long as the others, the ball of the eye, supported on that side only by soft parts, may be directed outwards, and take cognisance of objects placed to a side, without it being necessary, at the same time, to turn the head. In proportion as we descend from man in the scale of animated beings, the shape of the base of the orbits becomes more and more oblique; the eyes cease to be directed forward; in short, the external side of the socket disappears, and the sight is entirely directed outward; and, as the physiognomy derives its principal character from the eyes, its expression is absolutely changed. In certain animals very fleet in running, such as the hare, the lateral situation of the organs of vision prevents the animals from seeing small objects placed directly before them; hence those animals, when closely pursued, are so easily caught in the snares which are laid for them.

The organ of sight consists of three essentially distinct parts. The one set intended to protect the eye-ball, to screen it, at times, from the influence of light, and to maintain it in the conditions necessary to the exercise of its functions: these parts are the eye-brows, the eye-lids, and the lachrymal apparatus, and they serve as appendages of the organ. The eye-ball itself contains two parts, answering very different purposes; the one, formed by nearly the whole globe, is a real optical instrument, placed immediately in front of the retina, and destined to produce on the luminous rays those changes which are indispensable in the mechanism of vision; the other, formed by the medullary expansion of the optic nerve, is the immediate organ of that function. It is the retina which alone is affected by the impression of light, and set in motion by the contact of that very subtle fluid. This impression, this motion, this sensation, is transmitted to the cerebral organ by the optic nerve, the expansion of which forms the retina.

CXVI. *Of the eye-brows, the eye-lids, and the lachrymal apparatus* (*tutamina oculi*, Haller). The more or less dark colour of the hairs of the eye-brows renders that projection very well adapted to diminish the effect of too vivid a

light, by absorbing a part of its rays. The eye-brows answer this purpose the more completely, from being more projecting, and from the darker colour of the hairs which cover them ; hence we depress the eye-brows, by knitting them transversely, in passing from the dark into a place strongly illuminated, which causes an uneasy sensation to the organ of sight. Hence, likewise, the custom that prevails with some southern nations, whose eye-brows are shaded by thicker and darker hairs, to blacken them, that they may still better answer the purpose for which they are intended.

The eye-lids are two movable curtains placed before the eyes, which they alternately cover and uncover. It was requisite that they should be on the stretch, and yet capable of free motion ; now, both these ends are obtained by the tarsal cartilages, which are situated along the whole of their free edges, and of the muscles which enter into their structure. The cellular tissue which unites the thin and delicate skin of the eye-lids to the muscular fibres, contains, instead of a consistent fat, which would have impeded its motion, a gelatinous lymph, which, when in excess, constitutes œdema of the eye-lids. The tissue of the eye-lids is not absolutely opaque, since, even when strongly drawn together, and completely covering the globe of the eye, one may still discern through their texture light from darkness. On that account, light may be considered as one of the causes of awakening, and it is of consequence to keep in the dark patients fatigued by want of sleep.

The principal use of the eye-lids is to shade the eyes from the continual impression of light. Like all the other organs, the eyes require to recruit themselves by repose ; and they had not been able to enjoy it, if the incessant impression of the luminous rays had continually excited their sensibility. The removal of the eye-lids* is attended with loss of sleep. The fluids are determined to the affected organ, which suffers from incessant irritation. The eyes inflame, the inflammation spreads towards the brain, and the patient expires in the most dreadful agony. Thanks to an advanced state of civilisation, these barbarous tortures have long been abolished ; but what happens, when, from ectropium of one or other of the eye-lids, a small portion of the sclerotic coat or cornea remains uncovered, proves the indispensable necessity of those parts. The spot exposed to the continued action of the air and of the light becomes irritated and inflamed, and there comes on an ophthalmia, which can be cured only by bringing together, by means of a surgical operation, the divided edges of the opening which is the cause of the affection. From the movable edges of both eye-lids there arise short curved hairs, of the same colour as those of the eye-brows ; they are called eye-lashes, and are intended to prevent insects, or other very light substances floating in the atmosphere, from getting between the eye-ball and the eye-lids.†

The anterior part of the eye, thus defended against external injuries, is continually moistened by the tears. The organ which secretes this fluid is a small gland, situate in a depression at the anterior and external part of the arch of the orbit, imbedded in fat, and supplied with pretty considerable vessels and nerves in proportion to its bulk, and pouring the fluid it secretes, by means of seven or eight ducts which open on the internal surface of the upper eye-lid, by capillary orifices directed downward and inward. The tears are a muco-serous fluid, rather heavier than distilled water, saltish, changing to a green colour vegetable blues, and containing soda, muriate

* A mode of punishment in use amongst the ancients, especially the Carthaginians.

† They also absorb and intercept some of the luminous rays, and thus diminish the hurtful effects of too strong a light.—J. C.

and carbonate of soda, and a very small quantity of phosphate of soda and of lime.*

In ophthalmia, the irritation of the conjunctiva, transmitted by sympathy to the lachrymal gland, not only augments the quantity of its secretion, but appears likewise to alter the qualities of the fluid that is secreted. The tears, which in those cases flow in such profusion, bring on a sense of burning heat in the inflamed part. Do they not, perhaps, contain a greater quantity of the fixed alkali than in the ordinary state of the parts ? and may not the painful sensation depend as much on the increased proportion of soda in the tears, as on the greater sensibility of the conjunctiva ?

This last membrane is merely a fold of the skin, which is exceedingly thin, covers the posterior surface of the eye-lids, and is then reflected over the anterior part of the eye, which it thus unites to the eye-lids. From the whole extent of its surface there oozes an albuminous serosity, which mingles with the tears, and adds to their quantity.†

The tears are equably diffused over the globe of the eye by the alternate motions of the palpebræ ; they prevent the effects of friction, and save the organ of sight from being dried at that part which is exposed to the air. The air dissolves, and carries off in evaporation, a part of the lachrymal fluid. This evaporation of the tears is proved by the weeping, to which those in whom that secretion is very profuse are subject, whenever the atmospherical air, from being damp, does not carry off a sufficient quantity of the fluid. The unctuous and oily fluid secreted by the Meibomian glands, smears the loose edge of the palpebræ, prevents the tears from falling on the cheek, and answers the same purpose as the greasy substance with which one anoints the edges of a vessel filled above its level, to prevent the overflowing of the contained fluid.

The greatest part of the tears, however, flow from without inward and towards the inner canthus of the eye ; they take that direction in consequence of the natural slope of the movable edge of the palpebræ, of the triangular groove, which is formed behind the line of union of their edges, whose round and convex surfaces touch each other only in a point ; and this course of the tears is likewise promoted by the action of the palpebral portions of the orbicularis palpebrarum, whose fibres, having their fixed point at the inner angle of the orbit where the tendon is inserted, always draw inward their external commissure.

On reaching the internal angle of the palpebræ, the tears accumulate in the *lacus lachrymalis*, a small space formed between the edges of the palpebræ, kept separated from each other by the *caruncula lachrymalis*. This last substance, long considered by the ancients as the secretory organ of the tears, is merely a collection of mucous cryptæ, covered over by a loose fold of the conjunctiva. These follicles, alike in nature to the Meibomian glands, secrete, like them, an unctuous substance, which smears the movable edges

* The saline parts amount only to about 0·01 of the whole. The mucus contained in the tears has the property of absorbing oxygen from the atmosphere, and of becoming thick and viscid, and of a yellow colour. The circumstance of their acquiring new properties from the absorption of oxygen explains the changes which take place in the tears in some diseases of the eye. See the Chapter in the APPENDIX, on the Chemical Constitution of the Textures and Secretions, &c.—*J. C.*

† There is no opening in the skin at the part which corresponds to the globe of the eye ; it is exceedingly thin, and is continued, under the name of conjunctiva, over the transparent cornea, to which it adheres so firmly that it is not easily separated from it. In some animals that have no palpebræ, the skin is continued, of the same thickness, over the fore part of the eye. The conjunctiva (if, however, this portion of the skin deserves that name) when opaque, renders the globe of the eye, in other respects imperfect, absolutely useless. This is observed in the kind of eel called, in books of natural history, *murena cæcilia:* the *gastrobranchus cæcus* is blind from the same circumstance.—(*Richerand*). M. Ribes is of opinion that it terminates at the circumference of the cornea.

of the palpebræ, near the internal commissure. The edges of the eye-lids in this situation require a thicker coating, as the tears accumulated in that spot have no where a greater tendency to flow on the cheek.

Near the union of the inner sixth of the free edge of the palpebræ with the remaining five-sixths, at the outer part, where their internal, straight, or horizontal portion unites with the curved part, there are situated two small tubercles, at the top of each of which there is a minute orifice. These are the puncta lachrymalia, and they are called superior and inferior, according to the palpebræ to which they belong. In the dead body the puncta do not appear tubercular, the small bulgings, produced doubtless by a state of orgasm and of vital erection, collapse at the approach of death. These small apertures, directed inward and backward, are incessantly immersed in the accumulated tears, absorb them, and convey them into the lachrymal sac by means of the lachrymal ducts, of which they are the external orifices. The absorption of the tears, and their flow into a membranous reservoir lodged in the groove formed by the os unguis, do not depend on the capillary attraction of the lachrymal ducts ; each of them, endowed with a peculiar vital action, takes up, by a real process of suction, the tears accumulated in the *lacus lachrymalis*, and determines their flow into the sac. The weight of the fluid, the effort of the columns which succeed each other, co-operate with the action of the parietes of the duct. The flow of the tears is further facilitated by the compression and slight concussions attending the contractions of the palpebral fibres of the orbicularis, behind which the lachrymal ducts are situated.

The vitality of the puncta lachrymalia and of the ducts is readily discovered when we attempt to introduce into them Anel's syringe or Mejean's stylet, to remove slight obstructions of the lachrymal passages. In a child now under my care for a mucous obstruction of the nasal duct, I can see the puncta lachrymalia contract, when the extremity of the syphon does not at once enter the canal. One is then obliged to wait, before it can be introduced, for a cessation of the spasmodic contraction, which lasts but a few moments. The tears which flow into the lachrymal sac by the common orifice of the united puncta lachrymalia, never accumulate within it, except in case of morbid obstruction ; they, in that case at once enter into the nasal duct, which is a continuation of it, and fall into the nasal fossæ below the anterior part of the inferior turbinated bones of these cavities. There they unite with the mucus of the nose, increase its quantity, render it more fluid, and change its composition. The use of the tears is to protect the eye-ball against the irritating impression of the immediate contact of the atmosphere. They at the same time favour the sliding of the palpebræ, lessen the friction in those parts and in the eye-ball, and thus promote their motion.

CXVII. *Of the globe of the eye.*—The eye-ball, as was already observed, may be considered as a dioptrical instrument, placed before the retina, whose office it is to refract the luminous rays, and to collect them into one fasciculus, that may strike a single point of the nervous membrane exclusively calculated to feel its impression. An outer, membranous, hard, and consistent covering supports all its parts. Within the first membrane, called the sclerotic, lies the choroid, a darkish coat, which lines the inside of the sclerotic, and forms the eye into a real camera obscura.* At the anterior part of the

* Gmelin (Schweigger's Journ. vol. x. p. 507) made an interesting set of experiments in order to determine the composition of the black pigment which lines the choroid coat of the eye.

"Its colour," he informs us, "is blackish-brown ; it is tasteless, and adheres to the tongue like clay ; is insoluble in water, alcohol, ether, oils, lime-water, and distilled vinegar. It dissolves in potash and ammonia when assisted by heat, and is again precipitated by acids. Sulphuric acid dissolves it, and changes its colour to reddish-brown. When distilled, it yields

globe there is a circular opening in the sclerotic, in which the transparent cornea is inserted. At about the distance of a twelfth part of an inch from this convex segment, received in the anterior aperture of the sclerotica, lies the iris, a membranous partition, placed perpendicularly, and containing a round opening (the pupil), which dilates or contracts, according to the state of dilatation or contraction of the iris.

At the distance of about half a line from the back part of the iris, towards the union of the anterior fourth of the globe of the eye with the posterior three-fourths, opposite to the opening of the pupil, there is situated a lenticular body, enclosed in a membranous capsule, immovably fixed in its situation by adhering to the capsule of the vitreous humour.

Behind the crystalline lens the posterior three-fourths of the cavity of the eye contain a viscid transparent humour, enclosed in the cells of a remarkably fine capsule, called hyaloid. This vitreous humour forms about two-thirds of a sphere, from which the anterior segment had been taken out; the pulpous expansion of the optic nerve, the retina, is spread out on its surface so as to be concentrical to the choroid and sclerotic coats.

The eye-ball being nearly spherical, the length of its different diameters differs but little. The diameter of the eye, from the fore to the back part, is between ten and eleven lines; the transverse and vertical diameters are somewhat shorter. Within the space measured by the diameter from the fore to the back part, there are situated, taking them in their order from the fore part, the cornea; the aqueous humour contained in the anterior chamber; the iris, and its central opening or pupil; the aqueous humour of the posterior chamber; the crystalline lens, surrounded by the ciliary processes; then the vitreous humour in its capsule; and behind those transparent parts of the eye, through which the luminous rays pass in approaching to a perpendicular, are the retinæ, which receive the impression; the choroid, whose black point absorbs the rays that pass through the thin and transparent retina; and the sclerotic, in which there is an opening for the passage of the optic nerve to the globe of the eye.

The cornea, contained in the anterior aperture of the sclerotica, like the glass of a watch-case within its frame, is about the third of a line in thickness; it forms at the fore-part of the eye the segment of a smaller sphere, behind it lies the aqueous humour, which fills what are called the chambers of the eye; these form spaces, divided into anterior and posterior; the former, which is the larger of the two, bounded by the cornea at the fore part, and by the iris at the back part; the latter, which is smaller, and separates the crystalline humour from the iris, the posterior part of which, covered by a black pigment, is called the *uvea*.* The specific gravity of the aqueous humour

water, a brown oil, and carbonate of ammonia. It gives out at the same time carburetted hydrogen, carbonic oxide, azotic and oxygen gases. The coal remaining in the retort consists almost entirely of charcoal." Mich. Mondini (Osservaz. sull nero pigmento dell' occhio, &c.) contends that the dark colour of this pigment is owing to the presence in it of the oxide of iron. —*J. C.*

* Some anatomists have doubted the existence of the posterior chamber of the eye; but to be convinced of its existence, one need but to freeze an eye, when there will be found a piece of ice between the crystalline lens and the uvea. The formation of this icicle is not owing to the admission, through the opening of the pupil, of the aqueous humour. which, like all other fluids, expands considerably on freezing; for, the expansion of fluids on their freezing being proportioned to their bulk, the vitreous humour, which freezes at the same time as the aqueous, must prevent its retrograde flow through the pupil. Lastly, the uvea or posterior part of the iris is covered with a black point, which is easily detached from it: now, if the anterior part of the crystalline lens had been in immediate contact with it, it would have been soiled by some of this colouring matter, which would have tarnished its natural transparency, indispensable to perfect vision. It is, therefore, undeniable, that there does exist a posterior chamber, which is to the anterior in the proportion of two to five, and containing about two-fifths of the aqueous humour, the whole of which is estimated at five grains, and that the iris forms a loose partition between the two portions

does not much exceed that of distilled water; some have even thought it less; it is albuminous, and holds in solution several saline substances.* The crystalline, enclosed in its membranous and transparent capsule, is a lenticular body, rather solid than fluid; its consistence is particularly great towards its centre; it there forms a kind of nucleus, around which are several concentric layers, whose density diminishes as they approach the surface, where the external layers, truly fluid, form what Morgagni considered as a peculiar liquid, on which the lens might be nourished by a kind of imbibition. This body, composed of two segments of unequal convexity, about two lines in thickness at its centre, consists of an albuminous substance coagulable by heat and alcohol. Extremely minute arteries, given off by the central artery of Zinn, pass through the vitreous humour, and bring to it the materials of its growth and reparation.†

The vitreous humour, so called from its resemblance to melted glass, is less dense than the crystalline, and more so than the vitreous, and is in considerable quantity in the human eye: it appears to be secreted by the minute arteries which are distributed to the parietes of the membrane of the vitreous humour; it is heavier than common water, somewhat albuminous and saltish.‡

The sclerotica is a fibrous membrane, to which the tendons that move the globe of the eye are attached; it supports all the parts of that organ, and these collapse and decay whenever the continuity of its external covering is destroyed. The use of the choroid is not so much to afford a covering to the other parts, as to present a dark surface, destined to absorb the luminous rays, when they have produced on the retina a sufficient impression. If it were not for the choroid, the light would be reflected; after having impinged on the nervous membrane, its rays would cross, and produce only indistinct

of the aqueous humour in which the dark pigment of the uvea is insoluble. The aqueous humour appears to be the product of arterial exhalation; it is soon re-produced, as we see after the operation for cataract.

* *The aqueous humour.*—Specific gravity 1·090 at a temperature of 60. From various recent experiments it appears to be water slightly impregnated with—1st, Albumen; 2d, Gelatine; 3d, Muriate of soda. Its constituents, according to the analysis of Berzelius, are:—

Water	98·10
Albumen	a trace.
Muriates and lactates	1·15
Soda, with animal matter soluble only in water	·75
	100·00—*J. C.*

† *The crystalline lens.*—Its specific gravity is 1·100. When fresh it has little taste. It putrefies very rapidly. It is almost completely soluble in water. The solution is partly coagulated by heat, and gives a copious precipitate with tannin, both before and after the coagulation. Its composion, according to the analysis of Berzelius, is as follows:—

Water	58·0
Peculiar matter	35·9
Muriates, lactates, and animal matter soluble in alcohol	2·4
Animal matter soluble only in water with some phosphates	1·3
Portions of the remaining insoluble cellular membranes	2·4
	100·0

The peculiar matter of the lens possesses all the chemical characters of the colouring matter of the blood, except colour. When burnt it leaves a little ash, containing a very small portion of iron. When its solution in water is coagulated by boiling, the liquid in which the coagulum was formed reddens litmus, containing free lactic acid. (Ann. of Phil. vol. xi. p. 385.)—*J. C.*

‡ The *vitreous humour* possesses the same properties as the *aqueous*; even its specific gravity is the same, or only a very little greater. Its constituents, according the analysis of Berzelius, are:—

Water	98·40
Albumen	·16
Muriates and lactates	1·42
Soda, with animal matter soluble only in water	·02
	100·00.—*J. C.*

sensations. Mariotte thought that the choroid was the immediate seat of vision, and that the retina was only its epidermis. This hypothesis would never have obtained so much celebrity, if, besides the objections that analogy might have furnished against it, there had been adduced, in opposition to it, the fact observed in fishes, in which the choroid is separated from the retina by a glandular body, opaque, and incapable of transmitting the luminous rays. The retina loses its form as soon as it is separated from the vitreous humour, or from the choroid coat, between which it is spread out as a very thin capsule, so soft as to be almost fluid. A number of blood-vessels, from the central artery of Zinn, are distributed on the nervous substance of the retina, and give it a slight pink colour. Ought we, with Boerhaave, to attribute to aneurismal or varicose enlargements of those small vessels, the spots which are seen in objects, in the disease to which Maître Jean gave the name of *imaginations?* In order to form the retina, the optic nerve (which proceeds to the globe of the eye, by piercing the sclerotica, to which the covering given to that nerve by the dura mater is connected) penetrates through a very thin membrane, perforated by a number of small holes; and, closing the opening left for the nerve, and which belongs as much to the choroid as to the sclerotic coats, it then spreads out to furnish the expansion which lines the concavity of the choroid, and covers over the convex surface of the vitreous humour.* The whole extent of the retina, which is equally nervous and sentient, may receive the impression of the luminous rays; though this faculty has, by several philosophers, been exclusively assigned to its central part, called the optical axis, or porus opticus. This central part is easily recognised in man by a yellow spot discovered by Soëmmering; in the middle of this spot, situated at the outer side of the entrance of the optic nerve into the globe of the eye, there is seen a dark spot, and a slight depression, the use of which is not understood. This peculiar structure is met with only in the eye of man and of monkeys.†

CXIX. *Mechanism and phenomena of vision.*—The rays of light passing from any point of an enlightened object form a cone, of which the apex answers to the point of the object, and of which the base covers the anterior part of the cornea. All the rays, more diverging, which fall without the area of the cornea on the eye-brows, the eye-lids, and the sclerotica, are lost to vision. Those which strike the mirror of the eye pass through it, under a refraction proportioned to the density of the cornea, which much exceeds that of the atmosphere, and to the convexity of that membrane; approaching the perpendicular, they now pass through the aqueous humour, less dense, and fall upon the membrane called the iris. All those that fall upon this membrane are reflected, and shew its colour different in different persons, and

* The optic nerves differ very remarkably from the other cerebral pairs, both in their thickness, and in the delicacy of their substance, which appears to be an immediate continuation of the medullary fibres of the brain, to which the meninges furnish one common envelope, and not a distinct membranous canal for each fibre.

The nerves of vision cross each other before the cella turcica, in a manner similar to the primitive crossing, which their roots, as well as those of the other nerves, undergo in the substance of the brain. These double decussations may be said to neutralise each other; and, consequently, each optic nerve may be considered to arise primarily from the hemisphere corresponding to the eye which it supplies. In hemiplegia, the affected eye is not on that side of the body struck with the paralysis,—it is on the opposite side that the pupil is dilated; and this pathological phenomenon, which is easily proved in persons who have experienced a paralytic seizure, seems to be one of the best proofs which can be opposed to those who suppose that the optic nerves, where they approach each other, experience an approximation of their fibres only. It may be farther argued, in support of the actual decussation of these nerves, that the wasted optic nerve of an eye that has been for some time in a state of atrophy, can be traced towards the opposite lobe of the brain; and that an evident crossing of the optic nerves may be observed in many of the class of fishes. —*J. C.*

† See APPENDIX, Note E E.

apparently depending on the organic texture, and on the particular and very diversified arrangement of the nerves, of the vessels, and cellular tissue, which enter into its structure. None but the most central traverse the pupil and serve to sight. These will pass that opening, in greater or less number, as it is more or less dilated. Now, the pupil is enlarged or diminished by the contraction or expansion of the iris. The motions of this membrane depend entirely on the manner in which light affects the retina. The iris itself is insensible to the impression of the rays of light, as Fontana has proved, who always found it immovable when he directed on it alone the luminous rays. When the retina is disagreeably affected by the lustre of too strong a light, the pupil contracts, to give passage only to a smaller number of rays: it dilates, on the contrary, in gloom, to admit enough to make the requisite impression on the retina.

To explain the motions of the iris, it is not necessary to admit that muscular fibres enter into its structure;* it is enough to know its vascular,

* Some anatomists contend, and we think justly, that two sets of muscular fibres enter into the structure of the iris; the one radiant, and the other orbicular. Amongst those who have lately argued in support of this position, we may mention M. Maunoir of Geneva, and M. Edwards. Some anatomists consider the iris to be a tissue *sui generis*; whilst others rank it among the erectile structures. It appears to us, that those who deny muscularity to this part, do so in consequence of a mistaken idea, which seems to be too generally adopted, viz. that no part is really muscular but that which possesses fibres of a similar appearance to those which perform the function of voluntary motion. It should, however, be kept in recollection, that involuntary muscles—those fibrous textures which receive only nerves proceeding from the ganglia, which are not supplied with voluntary nerves, and which are consequently not directly influenced by the will—differ very essentially from voluntary muscles in their structure. Indeed muscular textures vary not only in their functions, but even in their external characters, according as they are more or less plentifully supplied with either class of nerves—the cerebral or ganglial. The structure also of muscular parts, especially those which are removed from the influence of volition, has some relation to the kinds of irritants by which they are designed to be influenced by Nature. Thus, the eye being formed with an intimate relation to the functions which it has to perform, and to the external influences which act on it, possesses in the structure of its iris a muscular texture of peculiar delicacy; and hence it is more sensible to the irritations which accompany, and are subservient to, the right performance of this important animal function.

If the structure of the iris, the number of the soft and delicate nervous fibrils which proceed to it from the lenticular ganglion and the nasal branch of the fifth pair, and the connexion which they form with the retina in their course, be kept in view, we shall readily be able to comprehend the procession of phenomena which lead to the motions of the iris. It is not improbable, that the nervous fibrils proceeding from the ganglion to the iris, form, with the capillary arteries which supply its cellular texture, that particular organisation which may be considered as muscular; or, in other words, that these ganglial nerves terminating conjunctly with capillary ramifications in the delicate cellular substance of the iris, constitute by such a disposition its particular structure, and enable it to perform its peculiar functions. Hence it will be seen, that impressions made upon the retina, (in the sensible state of that nervous expansion, and in proportion to the extent of its sensibility), and transmitted to the iris, by means of the connexion which exists between the retina and the nerves supplying the iris, cause a contraction of its circular fibres: as soon as such impressions cease, these fibres relax, and the comparative action in the circular and radiated fibres, giving rise to certain states of pupil, is relative to the conditions of the nervous system, and the extent to which the irritation proceeds along the axis of the nerves and vessels, and affects either set of fibres.

According to this view of the subject, compression of the brain, or an insensible state of the optic nerve, is followed by expansion of the pupil, because the impression requisite to contraction of the orbicular fibres cannot be made, unless occasionally to a small extent, owing to the loss of sensibility; and, consequently, the greater tonic power of the antagonist (the radiated) fibres predominates in preserving a permanently dilated state of the pupil. The pupil is also dilated in weak children, and in those afflicted with worms, conformably to what is generally observed in the animal economy, namely, that all orbicular muscles, when no adjoining irritation exists, evince a greater or less degree of relaxation as the vital energies are more or less diminished. It would appear that, in a debilitated state of the system, the nervous influence proceeding from the lenticular ganglion is insufficient to the purpose of exciting fully the orbicular fibres of the iris; and at the same time the retina perhaps possesses that low degree of sensibility to the irritation of light which is followed by an inadequate effect upon the nerves supplying the iris. Indeed, it seems, under the circumstances just referred to, where irritation generally is present in the abdominal viscera, that nervous influence is secreted in the brain and parts adjoining in an insufficient manner, and consequently the diminished activity of the cerebral and ganglial nerves supplying the various structures of the eye is the result. When, however, irritation exists in the

spongy, and nervous texture ; the irritation of the retina sympathetically transmitted to the iris determines a more copious afflux of humours ; its tissue dilates and stretches, the circumference of the pupil is pushed towards the axis of this opening, which becomes contracted by this vital expansion of the membranous tissue. When the irritating cause ceases to act, by our passing from light into darkness, the humours flow back into the neighbouring vessels, the membrane of the iris returns upon itself, and the pupil enlarges the more as the darkness is greater.

The rays admitted by the pupil pass through the aqueous humour of the posterior chamber, and soon meet the crystalline, which powerfully refracts them, both from its density and its lenticular form. Brought towards the perpendicular by this body, they pass on towards the retina through the vitreous humour, less dense, and which preserves, without increasing it, the refraction produced by the crystalline lens. The rays, gathered into one, strike on a single point of the retina, and produce the impression which gives us the idea of certain properties of the body which reflects them. As the retina embraces the vitreous humour, it presents a very extensive surface to the contact of the rays, which enables us to behold at once a great diversity of objects variously situated towards us, even when we or these objects change our relative situation*. The luminous rays refracted by the transparent parts of the eye, form therefore in the interior of the organ a cone, of which the base covers the cornea, and applies to that of the external luminous cone, whilst its apex is on some point of the retina. It is conceived, generally, that the luminous cones, issuing from all points of the object beheld, cross in their passage through the eye, so that the object is imaged on the retina reversed. Admitting this opinion, established on a physical experiment, we have to inquire why we see objects upright, whilst their image is reversed on the retina ? The best explanation we possess of this phenomenon we owe to the philosopher Berkeley, who proposed it in his English work, entitled *Theory of Vision, &c.* In his opinion, there is no need of the touch to correct this error into which sight ought to betray us. As we refer all our sensations to ourselves, the uprightness of the object is only relative, and its inversion really exists at the bottom of the eye.

By the *point of distinct vision* is understood the distance at which we can read a book of which the characters are of middling size, or distinguish any other object equally small. This distance is not confined within very narrow limits, since we can read the same book at six inches from the eye, or at five or six times the distance. This faculty of the eyes to adapt themselves to the distance and the smallness of objects, cannot depend, as has been fondly repeated, on the lengthening or shortening of the globe of the eye by the muscles that move it. Its four recti muscles are not, in any case, capable of compressing it on its sides, nor of lengthening it by altering its spherical form : their simultaneous action can only sink the ball in its socket, flatten it from the fore to the back part, diminish its depth, and make the refraction

brain, or when an increase of the circulation occurs in that organ, without overwhelming its powers, accompanied with or preceded by debility, the pupil contracts, or even remains contracted ; because, in consequence of such irritation or increase of circulation in the brain and connected parts, the sensibility and nervous activity are heightened.—*J. C.*

* The rays of light may be said to penetrate or traverse the demi-transparent tissue of the retina, and, as it were, to search through the nervous pulp when they arrive at the choroid coat, which is designed in a great measure to absorb these rays. Does any intimate combination take place between the nervous pulp and the light, which may give rise to that sensation which follows a violent compression of the globe of the eye in an obscure situation? The spots which are observable, after having had the eye fixed for a considerable time on certain coloured objects, do they arise from this sort of an impregnation of the retina, or rather of a portion of it with the rays of light?—or, as is more generally believed, has the sensibility of the retina become partially increased or diminished by the circumstance of inaction or of exercise ?

consequently less powerful when objects are very distant or very small: this last effect even might be disputed. The eye, which moves and rests on the adipose cushion that fills the bottom of the socket, is never strongly enough pressed to lose its spherical figure, which, of all the forms that bodies can be invested in, is that which, by its especial nature, best resists alteration. The extremities of the ciliary processes, which surround the circumference of the crystalline lens, cannot act on this transparent lens, compress, nor move it; for these little membranous folds, of which the aggregate composes the irradiated disk, known under the name of corpus ciliare, possessing no sort of contractile power, are incapable of moving the crystalline lens, with which their extremities, lying in simple contiguity, have no adherence, and which, besides, is immovably fixed in the depression it occupies by the adhesions of its capsule with the membrane of the vitreous humour. The various degrees of contraction or dilatation of which the eye-ball is susceptible, afford a much more satisfactory explanation of this physiological problem.

The rays of light which come from a very near object are very divergent: the eye would want the refracting power necessary to collect them into one, if the pupil, contracting by the enlargement of the iris, did not throw off the more divergent rays, or those which form the circumference of the luminous cone. Then those which form the centre of the cone, and which need but a much smaller refraction for their reunion on a single point of the retina, are alone admitted by the narrowed opening. When, on the contrary, we look at a distant object from which rays are given out, already very convergent, and which need but a small refraction to bring them towards the perpendicular, we dilate the pupil, in order to admit the more diverging rays, which, when collected, will give the image of the object. In this respect very small bodies are on the same footing as those at a great distance.

Though the image of every object is traced at the same time in both our eyes, we have but one sensation, because the two sensations are in harmony and are blended, and serve only, one aiding the other, to make the impression stronger and more durable. It has long been observed, that sight is more precise and correct when we use only one eye; and Jurine thinks that the power of the two eyes united exceeds only by one-thirteenth that of a single eye. The correspondence of affection requires the direction of the optical axes on the same objects; and, be that direction ever so little disturbed, we see really double, which is what happens in squinting.

If the eyes are too powerfully refractive, either by the too great convexity of the cornea and the crystalline, the greater density of the humours, or the excessive depth of the ball, the rays of light, too soon reunited, diverge anew, fall scattering on the retina, and yield only a confused sensation. In this defect of sight, called *myopia*, the eye distinguishes only very near objects, giving out rays of such extreme divergence as to require a very powerful refractor. In *presbytia*, on the other hand, the cornea too much flattened, the crystalline little convex, or set too deeply, the humours too scanty, are the cause that the rays are not yet collected when they fall upon the retina, so that none but very distant objects are distinctly seen, because the very* convergent rays they give out have no need of much refraction.

Myopia is sometimes the effect of the habit which some children get of looking very close at objects which catch their attention. The pupil then becomes accustomed to great constriction, and dilates afterwards with difficulty. It is obvious, that to correct this vicious disposition, you must shew the child distant objects which will strongly engage his curiosity, and keep him at some distance from every thing he looks at.

* The author means "scarcely divergent."—*T.*

The sensibility of the retina on some occasions rises to such excess that the eye can scarcely bear the impression of the faintest light. *Nyctalopes*, such is the name given to those affected with this disorder, distinguish objects amidst the deepest darkness: a few rays are sufficient to impress their organ.

It is related that an English gentleman, shut up in a dark dungeon, came gradually to distinguish all it contained: when he returned to the light of day, of which he had in some sort lost the habit, he could not endure its splendour; the edges of the pupil, before extremely dilated, became contracted to such a degree as entirely to efface the opening.

When, on the other hand, the retina has little sensibility, strong daylight is requisite to sight. This injury of vision, known by the name of *hemeralopia*,* may be considered as the first step of total paralysis of the optic nerve, or *gutta serena*. It may arise from any thing that can impair the sensibility of the retina. Saint-Yves relates, in his work on diseases of the eyes, many cases of hemeralopia. The subjects were chiefly workmen employed at the Hôtel des Monnoies, in melting the metals. The inhabitants of the northern regions, where the earth is covered with snow great part of the year, become at an early age hemeralopes. Both contract this weakness from their eyes being habitually fatigued by the splendour of too strong a light.

Finally, in order to the completion of the mechanism of vision, it is requisite that all parts of the eye be under certain conditions, the want of which is more or less troublesome. It is especially necessary that the membranes and the humours which the rays of light are to pass through should be perfectly transparent. Thus, specks of the cornea, the closing of the pupil by the preservation of the membrane which stops that opening during the first months of the life of the fœtus; cataract, an affection which consists in the opacity of the crystalline lens or its capsule; the glaucoma, or defect of transparency, in the vitreous humour,—weaken or altogether destroy sight, by impeding the passage of the rays to the retina. This membrane itself must be of tempered sensibility to be suitably affected by the contact of the rays of light. The choroid, the concavity of which it fills, must present a coating black enough to absorb the rays that pass through it. It is to the sensible decay of the dye of the choroid in advancing years, as much as to the collapsing induration and discolouring of different parts of the eye, and the impaired sensibility of the retina from long use, that we ascribe the confusion and weakness of sight in old people. The extreme delicacy of the eyes of the *Albinos* proves equally the necessity of the absorption of light by the black coating which covers the choroid.

Of all the organs of sense, the eyes are those which are the most developed in a new-born child;—they have then nearly the bulk which they are to retain during life. Hence it happens, that the countenance of children, whose eyes are proportionably larger, is seldom disagreeable, because it is chiefly in these organs that physiognomy seeks expression. Might we not say, that if Nature sooner completes the organ of sight, it is because the changes which it produces on the rays of light arising purely from a physical necessity, the perfection of the instrument was required for the exercise of the sense?

The eyes are not immovable in the place they occupy. Drawn into very

* I give to the words *nyctalopia* and *hemeralopia* the same meaning as all other writers down to Scarpa, who have published treatises on diseases of the eyes. This acceptation is, however, a grammatical error; since, of the two terms, *nyctalopia*, in its Greek roots, signifies an affection which takes away sight during the night; and *hemeralopia*, one in which it is lost during the day. It is accordingly in this sense that they are used by the father of physic. I owe this remark to Dr. Roussille Chamseru, who has carefully verified the text of Hippocrates, in the MSS. of the Imperial Library.

various motions, by four *recti* muscles and two *oblique*, they direct themselves towards all objects of which we wish to take cognizance: and it is observed, that there is, between the muscles which move the two eyes, such a correspondence of action, that these organs turn at once the same way, and are directed at once towards the same object, in such a manner that the visual axes are exactly parallel. It sometimes happens that this harmony of motion is disturbed, and thence *squinting*,—an affection which, depending almost always on the unequal force of the muscles of the eye, may be distinguished into as many species as there are muscles which can draw the globe of the eye into their direction, when from any cause they become possessed of a predominating power. Buffon has further assigned as a cause of squinting, the different aptitude of the eyes to be affected by light. According to this celebrated naturalist, it may happen, that one of the eyes being originally of greater sensibility, the child will close the weaker to use the stronger, which is yet strengthened by exercise, whilst repose still weakens the one that remains in inaction. The examination of a great many young people who had fallen under military conscription, and claimed exemption on the score of infirmities, has shewn me that squinting is constantly connected with the unequal power of the eyes. Constantly, the inactive eye is the weakest, being almost useless; and it was quite a matter of necessity that the diverging globe should be thus *neutralised*, else the image it would have sent to the brain, different from that which the sound eye gives, would have introduced confusion into the visual functions. The squinting eye, being inactive, falls by degrees into that state of debility, from default of exercise, which Brown has so well called indirect debility.

The sense of sight appears to me much rather to deserve the name which J. J. Rousseau has given to that of smell, of sense of the imagination. Like that brilliant faculty of the soul, the sight, which furnishes us with ideas so rich and varied, is liable to betray us into many errors. It may be doubted whether it gives the notion of distance, since the boy couched by Cheselden conceived every thing he saw to touch his eye. It exposes us to false judgments on the form and size of objects; since, agreeably to the laws of optics, a square tower seen at a distance appears to us round; very lofty trees seen also very far off, seem no taller than the shurbs near us; a body moving with great rapidity appears to us motionless, &c. It is from the touch that we gain the correction of these errors, which Condillac, in his treatise on sensation, has perhaps exaggerated.

CXX. *Of the organ of sight in the lower animals.*—The organ of sight in different animals varies according to the medium in which they live; thus, in birds which fly in the higher regions of the air, there is an additional and very remarkable eye-lid: this is particularly the case with the eagle, which is thus enabled to look at the sun; and with night-birds, whose very delicate eye it seems to protect from the effects of two strong a light. In birds, likewise, there is a copious secretion of tears, the medium in which they live causing a considerable evaporation. The greater part of fishes, on the contrary, have no movable eye-lid, and their eyes are not moistened by tears, as the water in which they are immersed answers the same purpose. In some fishes, however, the eyes are smeared with an unctuous substance calculated to prevent the action of the water on the organ.

The globe of the eye in birds is remarkable for the convexity of the cornea, which is sometimes a complete hemisphere; hence it possesses a considerable power of refraction. This power of refraction appears to be very weak in fishes, the forepart of their eyes being very much flattened; but the water in which they live made it unnecessary that they should have an aqueous

humour, for the density of this fluid being nearly the same as that of water, it would not have produced any refraction; besides, being in sea-fish of inferior density to that of salt water, it would have broken the rays of light by making them diverge from the perpendicular. In fact, the refractive power of a medium is never but a relative quantity; the degree of refraction is not determined by the density of the medium, but by the difference of density between it and the medium that is next to it. To make up for the flatness of the cornea occasioned by the small quantity, or even by the absence, of aqueous humour, fishes have a very dense and spherical crystalline humour, the spherical part of which forms a part of a small sphere.

The eyes of birds, whose cornea is thrust out by a very copious aqueous humour, possess, in consequence of the presence of this fluid, a very considerable power of refraction; the air, in its higher regions, owing to its extreme rarefaction, being but little calculated to approximate the rays of light.

The pupil admits of greater dilatation in the cat, in the owl, in night-birds, and in general in all animals that see in the dark. The sensibility of the retina is, likewise, greater in those animals; several of them appear incommoded by the light of day, and never pursue their prey but in the most obscure darkness.

The crystalline humour of several aquatic fowls, as the cormorant, is spherical like that of fishes; and this is not, as will be mentioned hereafter, the only peculiarity of structure in this kind of amphibious animals. Lastly, the choroid of some animals, more easily separated into two distinct laminæ than that of man, presents, at the bottom of the eye, instead of a darkish, uniformly diffused coating, a pretty extensive spot of various colours, and in some it is most beautiful and brilliant. It is not easy to say what is the use of this coloured spot, known by the name of *tapetum*.

The rays of light reflected by this opaque substance, in passing through the eye, cross those which are entering at the same time; they must, consequently, prevent distinct vision, or at least impair the impression, in a manner which it is impossible to determine. It has been said, that the lower animals, provided with less perfect and often less numerous senses than those of man, must have different ideas of the universe: is it not likewise probable, that in consequence of the indistinct vision occasioned by the reflection from the tapetum, they may entertain erroneous and exaggerated notions of the power of man? And notwithstanding the power granted to man by the Creator over the lower animals, as we are told in the book of Genesis, is it probable that those which Nature has gifted with prodigious strength, or with offensive weapons, would obey the lord of the creation, if they saw him in his feeble and destitute condition,—in a word, such as he is?

The head of insects with numerous eyes is joined to their body, and moves along with it: their existence is, besides, so frail, that it was requisite that Nature should furnish them abundantly with the means of seeing those objects which may be injurious to them. We shall not enter any farther into these remarks relative to the differences in the organ of sight in the various kinds of animals: more ample details on this subject belong, in an especial manner, to comparative anatomy.*

CXXI. *Of sound.*—Sound is not, like light, a body having a distinct existence; we give the name of sound to a sensation which we experience whenever the vibrations of an elastic body strike our ears. All bodies are capable of producing it, provided their molecules are susçeptible of a certain degree of re-action and resistance. When a sonorous body is struck, its integrant particles experience a sudden concussion, are displaced, and oscillate

* For some further remarks on the Organ and Sense of Vision, see APPENDIX, Note E E.

with more or less rapidity. This tremulous motion is communicated to the bodies applied to its surface: if we lay our hand on a bell that has been struck by its clapper, we feel a certain degree of this trembling. The air, which envelopes the sonorous body, receives and transmits its vibrations with the more effect from being more elastic. Hence it is observed that, *cæteris paribus*, the voice is heard at a greater distance in winter, when the air is dry and condensed by the cold.

The sonorous rays are merely series of particles of air, along which the vibration is transmitted from the sonorous body to the ear which perceives the noise occasioned by its percussion. These molecules participate in the vibrations which are communicated to them; they change their form and situation in proportion as they are nearer to the body that is struck, and *vice versâ;* for, sound becomes weaker in proportion to the increase of distance. But this oscillatory motion of the aerial molecules should be well distinguished from that by which the atmosphere, agitated by the winds, is transported and changes its situation. And in the same manner as the balance of a pendulum moves incessantly within the same limits, so this oscillatory motion affects the molecules of the air within the space which they occupy, so that they move to and fro during the presence or the absence of the vibration. The atmospherical air, when set in motion in a considerable mass at a time, produces no sound, unless in its course it meets with a body which vibrates from the percussion which it experiences.

The force of sound depends entirely on the extent of the vibrations experienced by the molecules of the sonorous body. In a large bell struck violently, the agitation of the molecules is such that they are transmitted to considerable distances, and that the form of the body is evidently changed by it. Acute or grave sounds are produced by the greater or smaller number of vibrations in a given time, and the vibrations will be more numerous the smaller the length and diameter of the body. Two catgut strings, of the same length and thickness, and with an equal degree of tension, will vibrate an equal number of times in a given period, and produce the same sound. This, in music, is called *unison.* If one of the strings is shortened by one-half, it vibrates as often again as the other, and gives out a sound more acute, or higher by one *octave.* The same result may be obtained by reducing the string one-half of its original thickness, without taking from its length. The vibrations will, in the same manner, be accelerated by giving a greater degree of tension to the sonorous cord. The difference of the sounds produced by a bass, a harp, or any other stringed instrument, depends on the unequal tension, length, and size of the strings.

This division of the elementary sound is an act of the understanding, which distinguishes, in a noise apparently monotonous, innumerable varieties and shades, expressed by signs of convention. But in the same manner as light, refracted by a prism, presents innumerable intermediate shades between the seven primitive colours, and as the transition is gradual from one to the other of these colours; so the division of the primitive sound into seven tones, expressed by notes, is not absolute, and there are a number of intermediate sounds which augment or diminish their value, &c.

Sound has, therefore, been analysed as well as light: the use of the ear with regard to sound corresponds to that of the prism with regard to light; and the modifications of which sound is capable are as numerous and as various as the shades between the primitive colours.

Sound is propagated with less velocity than light. The report of a cannon fired at a distance is heard only a moment after the eye has perceived the flash of the explosion. Its rays diverge and are reflected, like those of light,

when they meet with an obstacle at an angle equal to that of incidence. The force of sound, like that of light, may be increased, by collecting and concentrating its rays. The sonorous rays which strike a hard and elastic body, when reflected by it, impart to it a vibratory motion, giving rise to a secondary sound, which increases the force of the primitive sound.

When these secondary sounds, produced by the percussion of a body at a certain distance, reach the ear, they give rise to what is called an echo. Who is unacquainted with the ingenious allegory by which its nature is expressed in ancient mythology, in which echo was called daughter of the air and earth?

CXXII. *Of the organ and mechanism of hearing.*—The organ of hearing in man consists of three very distinct parts; the one, placed externally, is intended to collect and to transmit the sonorous rays which are modified in passing along an intermediate cavity, between the external and internal ear. It is within the cavities of this third part of the organ, excavated in the substance of the petrous portion of the bone, that the nerve destined to the perception of sound, exclusively resides. The external ear and the meatus auditorius externus may be compared to an acoustic trumpet, the broad part of which, represented by the concha, collects the sonorous rays, which are afterwards transmitted along the contracted part, represented by the meatus externus. The concha contains several prominences separated by corresponding depressions; its concave part is not wholly turned outward; in those who have not laid their ears flat against the side of the head by tight bandages, it is turned slightly forward, and this arrangement, favourable to the collection of sound, is particularly remarkable in savages, whose hearing, it is well known, is remarkably delicate. The base of the concha consists of a fibro-cartilaginous substance, thin, elastic, calculated to reflect sounds, and to increase their strength and intensity by the vibrations to which it is liable. This cartilage is covered by a very thin skin, under which no fat is collected that could impair its elasticity: these prominences are connected together by small muscles, which may relax it by drawing the projections together, and thus place it in unison with the acute or grave sounds. These small muscles within the external ear, as the musculi helicis major and minor, the tragicus and anti-tragicus, and the transversus auris, are like the muscles on the outer part of the ear, stronger and more developed in timid animals with long ears. In the hare the fibre of these muscles are more distinctly marked; their action is most apparent in this feeble and fearful animal, which has no resource but in flight against the dangers which incessantly threaten its existence, and which required that it should receive early intimation of the approach of danger: hence hares have the power of making their ears assume various forms, of shaping them into more advantageous trumpets, of moving them in every direction, of directing them towards the quarter from which the noise proceeds, so as to meet the sounds and collect the slightest.

The form of the external ear is not sufficiently advantageous in man, whatever Boerhaave may have said to the contrary, to enable all the sonorous rays, which in striking against it are reflected at an angle equal to that of their incidence, to be directed towards the meatus auditorius externus. United for the most part into a single fasciculus, and directed towards the concha, they penetrate into the meatus auditorius externus, and the tremulous motions which they excite in its osso-cartilaginous parietes contribute to increase their force. On reaching the bottom of the meatus, they strike against the membrana tympani, a thin and transparent septum, stretched between the bottom of the meatus, and the cavity in which the small bones of the ear are lodged. These small bones form a chain of bone which cross-

es the tympanum from without inward, and which extends from the membrana tympani to that which connects the base of the stapes to the edge of the fenestra ovalis.

An elastic air, continually renewed by the Eustachian tube, fills the cavity of the tympanum; small muscles attached to the malleus and stapes move these bones, or relax the membranes to which they are attached, and thus institute a due relation between the organ of hearing and the sounds which strike it. It will be easily conceived, that the relaxation of the membrana tympani, effected by the action of the anterior muscle of the malleus, must weaken acute sounds; while the tension of the same membrane, by the internal muscles of the same bone, must increase the force of the grave sounds. In the same manner as the eye, by the contraction or dilatation of the pupil, accommodates itself to the light, so as to admit a greater or smaller number of its rays, according to the impression which they produce, so by the relaxation or tension of the membrane of the tympanum, or of the fenestra ovalis, the ear reduces or increases the strength of sounds, whose violence would affect its sensibility in a painful manner, or whose impression would be insufficient. The iris and the muscles of the stapes and of the malleus are, therefore, the regulators of the auditory and visual impression; there is as close a sympathetic connexion between these muscles and the auditory nerve as between the iris and the retina. The air which fills the tympanum is the true vehicle of sound; this air diffuses itself over the mastoid cells, the use of which is to augment the dimensions of the tympanum, and the force and extent of the vibrations which the air experiences within it.

These vibrations, transmitted by the membrana tympani, are communicated to those membranes which cover the fenestra ovalis and the fenestra rotunda; then, by means of these, to the fluid which fills the different cavities of the internal ear, and in which lie the soft and delicate filaments of the auditory nerve, or of the portio mollis of the seventh pair.

The agitation of the fluid affects these nerves, and determines the sensation of grave or acute sounds, according as they are slower or more rapid. It appears that the diversity of sounds should rather be attributed to the more or less rapid oscillations, and to the undulations of the lymph of Cotunni, than to the impressions on filaments of different lengths of the auditory nerve. These nervous filaments are too soft and too slender to be traced to their extreme terminations. It is, however, probable, that the various forms of the internal ear (the *semicircular* canals, the *vestibule*, and the *cochlea*), have something to do with the diversity of sounds. It must also be observed, that the cavities of the ear are contained in a bony part, harder than any other substance of the same kind, and well fitted to maintain, or even to augment by the re-action of which it is capable, the force of the sonorous rays.*

The essential part of the organ of hearing, that which appears exclusively employed in receiving the sensation of sounds, is, doubtless, that which exists in all animals endowed with the faculty of hearing. This part is the soft pulp of the auditory nerve, floating in the midst of a gelatinous fluid, contained in a thin and elastic membranous cavity. It is found in all animals, from man to the sepia. In no animal lower in the scale of animation has an organ of hearing been met with, although some of these inferior animals do not seem to be absolutely destitute of that organ. This gelatinous pulp

* If the cavities of the internal ear were hermetically sealed, it may be conceived that the violent undulations of the lymph of Cotunni would injure the nervous pulp; but the most violent agitation of this fluid does not amount to such a height, for it may flow towards the internal surfaces of the cranium by means of the two small conduits named *aqueducts.*—*J. C.*

is in the lobster contained in a hard and horny covering. In animals of a higher order its internal part is divided into various bony cavities. In birds there is interposed a cavity between that which contains the nerve of hearing and the outer part of the head; in man and in quadrupeds the organ of hearing is very complicated; it is enclosed in an osseous cavity, extremely hard, situated at a considerable depth, and separated from the outer part of the head by a cavity and a canal, along which the sonorous rays are transmitted, after having been collected into fasciculi by trumpets situated on the outside.

This kind of natural analysis of the organ of hearing is well calculated to give accurate notions of the nature and importance of the functions fulfilled by each of its parts. But in the investigation of the uses and of the relative importance of the auditory apparatus, morbid anatomy furnishes data of an equal value with those obtained from comparative anatomy.

CXXIII. *Pathological physiology of hearing.*—The external ear may be removed with impunity in man, and even in animals in which its form is more advantageous: the hearing is at first impaired, but at the end of a few days recovers its wonted delicacy. The entire obliteration of the meatus auditorius externus is attended with complete deafness. It is not essentially necessary for the mechanism of hearing that the membrana tympani should be whole; persons in whom it has been accidentally ruptured can force out smoke at their ears without losing the power of hearing; it may be conceived, however, that if, instead of having merely a small opening that would not prevent its receiving the impression of the sonorous rays, nor its being acted upon by the handle of the malleus, the membrana tympani were almost entirely destroyed, deafness would be the almost unavoidable consequence.* If, owing to the obstruction of the Eustachian tube, the air in the tympanum is not renewed, it loses its elasticity, and combines with the mucus within the tympanum. The cavity of the tympanum is then in the same condition as an exhausted receiver, in which the sonorous rays are transmitted with difficulty. It has been thought that the use of the Eustachian tube was, not only to renew the air contained in the tympanum, but also to transmit the sonorous rays into that cavity. In listening attentively, we slightly open our mouth; in order, it is said, that the sound may pass from this cavity into the pharynx, and thence reach the organ of hearing. This explanation is far from satisfactory; for the obliteration of the meatus auditorius externus is attended with complete deafness, which would not happen if the Eustachian tubes transmitted the sonorous rays. When a man listens attentively, and with his mouth open, the condyles of the lower jaw, situated in front of the external auditory meatus, being depressed and brought forward, the openings are evidently enlarged, as may be ascertained by putting the little finger into one's ear, at the moment of depressing the lower jaw.† The luxation of the small bones of the ear, or even their complete destruction, does not occasion deafness; the only consequence is, a confusion in the perception of sounds. When, however, the stapes, the base of which rests on the greatest part of the fenestra ovalis, or when the thin membrane

* We find that a temporary obstruction of the Eustachian tube in guttural angina is sufficient to occasion a considerable degree of deafness. In such a case the inflammation of the mucous membrane of the pharynx extends itself to that which lines the tube, of which it is a continuation; and the effects that the inflammation produces on the function of the organ are proportionate to the extent to which it advances in the different departments of the internal ear.—*J. C.*

† The open state of the mouth in an attentive listener, by no means proves that the sonorous rays are introduced along the Eustachian tube. Indeed, if such were the case, the aërial pulsations arriving by this tube would strike the tympanum in an opposite direction to those that are admitted by the external passage, and thus render the hearing confused. The purpose, therefore, which the Eustachian tube performs is nothing more than to allow the renewal of the air within the tympanum.—*J. C.*

which closes the fenestra ovalis, or when that which closes the fenestra rotunda, is destroyed, deafness takes place in consequence of the escape of the fluid which fills the cavities in which the auditory nerve is distributed.

The existence of this fluid appears essential to the mechanism of hearing; either from its keeping the nerves in the soft and moist state required for the purpose of sensation, or from its transmitting to them the undulatory motion with which it is agitated.

The deafness of old people, which, according to authors, depends on the impaired sensibility of the nerves, whose excitability has been exhausted by impressions too frequently repeated, appears sometimes to be occasioned by a deficiency of this humour, and by the want of moisture in the internal cavities of the ear. During the severe winter of 1798, professor Pinel opened, at the Hospital of Saltpêtrière, the skulls of several women who died at a very advanced age, and who had been deaf for several years. The cavities of the internal ear were found quite empty; they contained an icicle in younger subjects who had possessed the power of hearing.

Deafness may likewise be produced by a palsy of the portio mollis of the seventh pair, or by a morbid condition of the part of the brain from which this nerve arises. The mechanical explanation applied by Willis to the anomalous affections of the organ of hearing, is inadmissible,—those in which that organ is sensible only to the impression of weak or strong sounds acting together or separately.

This author relates the case of a woman who could not hear unless a great noise was made near her, either by beating a drum or by ringing a bell, because, says he, under such circumstances these loud noises determine in the membrana tympani, which he supposes in a state of relaxation, the degree of tension required to enable it to vibrate under the impression of weaker sounds. This membrane, to present greater resistance, must be put on the stretch by the internal muscle of the malleus, or by its own contraction. The total absence of muscular fibres in the membrana tympani in man, renders very doubtful this spontaneous contraction. Mr. Home, however, has just ascertained that the membrana tympani of the elephant is muscular and contractile. Admitting all these suppositions, we only substitute one difficulty for another, and it remains to be shewn, why the more powerful sounds merely increase the tone of the membrana tympani; why they do not become objects of perception of the organ of hearing, though they might be expected to render us insensible to the perception of weaker sounds.

CXXIV. *Of odours.*—Chemists have long thought that the odoriferous parts of bodies formed a peculiar principle, distinct from all the other substances entering into their composition; they gave it the name of *aroma*. M. Fourcroy, however, has clearly shewn, that this pretended element consisted merely of minute particles of bodies, detached by heat and dissolved in the atmosphere, which becomes loaded with them, and conveys them to the olfactory organs. According to this theory, all bodies are odoriferous, since caloric may sublimate some of the particles of those which are least volatile. Linnæus and Lorry had endeavoured to class odours according to the sensations which they produce;* M. Fourcroy has been guided by the chemical

* Linnæus admits seven classes of odours: 1st class, *ambrosiac* odours, those of the rose and of musk belong to this class,—they are characterised by their tenacity; 2d, *fragrant*,—for example, the lily, the saffron, and the jasmine,—they fly off readily; 3d, *aromatic*, as the smell of the laurel; 4th, *aliaceous*, approaching to that of garlic; 5th, *fetid*, as that of valerian and fungi; 6th, *virous*, as of poppies and opium; 7th, *nauseous*, as that of gourds, melons, cucumbers, and, in general, all cucurbitaceous plants.

Lorry admits only five kinds of odours, *camphorated*, *narcotic*, *ethereal*, *volatile-acid*, and *alkaline*.

M. Fourcroy admits the *mucous* aroma belonging to plants, improperly termed inodorous. *Oily and fugacious*, *oily and volatile*, *acid* and *hydro-sulphureous*.

nature of substances: but, however advantageous this last classification may be, it is difficult to include in it the infinite variety of odours which exhale from substances of all kinds; and it is perhaps as difficult to arrange them in classes, as the bodies from which they are produced.

This being laid down on the nature of odours, it is next explained why the atmosphere becomes loaded with the greater quantity, the warmer and the more moist it is. We know that in a flower-garden the air is at no time more loaded with fragrant odours, and the smell is never the source of greater enjoyment, than in the morning, when the dew is evaporating by the rays of the sun. It is, likewise, easily understood why the most pungent smells generally evaporate very readily, as æther, alcohol, the spirituous tinctures, and essential volatile oils.

CXXV. *Of the organ of smell.*—The nasal fossæ, within which this organ is situated, are two cavities in the depth of the face, and extending backward into other cavities, called frontal, ethmoideal, sphenoideal, palatine, and maxillary sinuses.

A pretty thick mucous membrane, always moist, and in the tissue of which the olfactory nerves and a considerable number of other nerves and vessels are distributed, lines the nostrils, and extends into the sinuses which communicate with them and covers their parietes throughout their windings and prominences. This membrane, called *pituitary*, is soft and fungous, and is the organ which secretes the mucus of the nose; it is thicker over the turbinated bones which lie within the olfactory cavities; it grows thinner and firmer in the different sinuses.

The smell appears more delicate in proportion as the nasal fossæ are more capacious, and the pituitary membrane covers a greater space. The soft and moist condition of the membrane is likewise essentially necessary to the perfection of this sense. In the dog, and in all animals which have a very exquisite sense of smell, the frontal, ethmoideal, sphenoidal, palatine, and maxillary sinuses, are prodigiously capacious, and the parietes of the skull are in great measure hollowed by these different parts of the olfactory apparatus; the turbinated bones are likewise very prominent in them, and the grooves between them very deep; lastly, the nerves of the first pair are large in proportion. Among the animals possessed of great delicacy of smell, few are more remarkable than the hog. This impure animal, accustomed to live in the most offensive smells and in the most disgusting filth, has, however, so very nice a smell, that it can detect certain roots, though buried in the earth at a considerable depth. In some countries this quality is turned to advantage, and swine are employed in looking for truffles. The animal is taken to those places where they are suspected to be, turns up the earth in which they are buried, and would feed on them greedily, if the herdsman, satisfied with this indication, did not drive them away from this substance intended for more delicate palates.

CXXVI. *Of the sensation of odours.*—Do the nerves of the first pair alone give to the pituitary membrane the power of receiving the impression of smell, and do the numerous filaments of the fifth pair merely impart to it the general sensibility belonging to other parts? This question appears to require an answer in the affirmative. The pituitary membrane, in fact, possesses two modes of sensibility perfectly distinct, since the one of the two may be almost completely destroyed, and the other considerably increased. Thus, in violent catarrh, the sensibility of the part, as far as relates to the touch, is very acute, since the pituitary membrane is affected with pain; while the patient is insensible to the strongest smells.

It seems probable, that the olfactory nerves do not extend into the sinuses,

and that these improve the sense of smell merely by retaining, for a longer space of time, a considerable mass of air, loaded with odoriferous particles. I have known detergent injections, strongly scented, thrown into the antrum Highmorianum by a fistula in the alveolar processes, produce no sensation of smell. A phial filled with spirituous liquor having been applied to a fistula in the frontal sinuses, gave no impression to the patient. The true seat of the sense of smell is at the most elevated part of the nostrils, which the nose covers over in the form of a capital. There the pituitary membrane is moister, receives into its tissue the numerous filaments of the first pair of nerves, which, arising by two roots from the anterior lobe of the brain, and from the fissure which separates it from the posterior lobe, passes from the cranium, through the openings of the cribriform plate of the ethmoid bone, and terminates by the expansion of its filaments forming a kind of parenchymatous tissue, not easily distinguished from that of the membrane. The olfactory papillæ would soon be destroyed by the contact of the atmospherical air, if they were not covered over by the mucus of the nose. The use of this mucus is, not merely to preserve the extremities of the nerves in a sentient state, by preventing them from becoming dry, but likewise to lessen the too strong impression that would arise from the immediate contact of the odoriferous particles. It perhaps even combines with the odours, and these affect the olfactory organs only when dissolved in mucus, as the food in saliva.

As the air is the vehicle of odours, these affect the pituitary membrane only when we inhale it into the nostrils. Hence, when any odour is grateful to us, we take in short and frequent inspirations, that the whole of the air which is received into the lungs may pass through the nasal fossæ. We, on the contrary, breathe through the mouth, or we suspend respiration altogether, when smells are disagreeable to us.

The sense of smell, like all the other senses, is readily impressed in children, though the nasal fossæ are in them much contracted, and though the sinuses are not yet formed. The general increase of sensibility at this period of life makes up for the imperfect state of the organisation, and it is in this respect with the nasal fossæ as with the auditory apparatus, of which an important part, the meatus externus, is then not completely evolved. The sense of smell is perfected by the loss of some of the other senses;—every body, for example, knows the history of the blind man whom that organ enabled to judge of the continence of his daughter,—it becomes blunted by the application of strong and pungent odours. Thus, snuff changes the quality of the mucus secreted by the membrane of the nose, alters its tissue, dries its nerves, and in the course of time impairs their sensibility.

The shortness of the distance between the origin of the olfactory nerves in the brain, and their termination in the nasal fossæ, render very prompt and easy the transmission of the impressions which they experience. This vicinity to the brain induces us to apply to those nerves those stimulants calculated to rouse the sensibility when life is suspended, as in fainting and asphyxia. The sympathetic connexions between the pituitary membrane and the diaphragm account for the good effects of sternutatories, in cases of apparent death.*

CXXVII. *Of flavours.*—Flavours are no less varied and no less numerous than odours, and it is as difficult to reduce them to general classes connected by analogies and including the whole.† Besides, there exists no element of

* For some remarks on the Organ and Sense of Smell, see APPENDIX, Notes F F.—*J. C.*

† This has been attempted, though with indifferent success, by Boerhaave, Haller, and Linnæus. *Acid*, *sweet*, *bitter*, *acrid*, *saltish*, *alkaline*, *vinous*, *spirituous*, *aromatic*, and *acerb*, were the terms employed by those physicians to express the general characters of flavours.

flavour, any more than an odoriferous principle. The flavour of fruits alters as they ripen, and appears to depend on the inward composition of bodies, on their peculiar nature, rather than on the form of their molecules; since crystals of the same figure, but belonging to different salts, do not produce similar sensations.

To affect the organ of taste, a body should be soluble at the ordinary temperature of the saliva; all insoluble substances are insipid; and one might apply to the organ of taste this celebrated axiom in chemistry, *corpora non agunt nisi soluta.* If there is a complete absence of saliva, and if the body that is chewed is altogether without moisture, it will affect the parched tongue only by its tactile, and not at all by its gustatory, qualities. The substances which have most flavour are those which yield most readily to chemical combinations and decompositions, as acids, alkalies, and neutral salts. When, in affections of the digestive organs, the tongue is covered with a mucous or whitish fur, or of a yellowish or bilious colour, we have only incorrect ideas of flavours; the thinner or thicker coating prevents the immediate contact of the sapid particles; when they act, besides, on the nervous papillæ, the impression which they produce is lost in that occasioned by the morbid contents of the stomach; hence every aliment appears bitter while the bilious disposition exists, and insipid in those diseases in which the mucous elements prevail.

CXXVIII. *Of the sense of taste.*—No sense is so much akin to that of the touch, or resembles it more. The surface of the organ of taste differs from the common integuments only in this respect, that the chorion, the mucous body, and the epidermis which envelop the fleshy part of the tongue, are softer, thinner, and receive a greater quantity of nerves and vessels, and are habitually moistened by the saliva, and by the mucus secreted by the mucous glands contained in their substance. These mucous cryptæ, and the nerves of the cutaneous covering of the tongue, raise the very thin epidermis which covers its upper surface, and form a number of papillæ, distinguished by their form into *fungous*, *conical*, and *villous*. With the exception of the first kind, these small prominences are formed by the extremities of nerves, surrounding a plexus of capillary blood-vessels, which give to these papillæ the power of becoming turgid and prominent, and of being affected with a kind of erection when we eat highly-seasoned food, or when we long for a savoury dish. The fungous papillæ are mostly situated at the remotest part of the upper surface of the tongue, towards its root, where it forms a part of the isthmus faucium. The pressure with which they are affected by the alimentary bolus, in its passage from the mouth into the pharynx, squeezes out the mucus which lubricates the edges of the aperture, and serves to promote its passage: these mucous follicles fulfil, in this respect, the same office as the amygdalæ.

The upper surface of the tongue is the seat of taste; it is undeniable, however, that the lips, the gums, the membrane lining the arch of the palate, and the velum palati,* may be affected by the impression of certain flavours.

It is observed in the different animals, that the organ of taste is more perfect according as the nerves of the tongue are larger, its skin thinner and

The flavour of any substance appears chiefly to arise from the odoriferous particles which escape from it, during the process of mastication and deglutition, through the posterior nares, and affect the olfactory nerves in that situation.—*J. C.*

* Especially the anterior part of the palatine membrane. The naso-palatine nerve, discovered by Scarpa, after arising from the ganglion of Mekel, and going for a pretty considerable distance into the nasal fossæ, terminates in that thick and rugous portion of the palatine membrane situated behind the upper incisors, and with which the tip of the tongue is in such frequent contact.

moister, its tissue more flexible, its surface more extensive, its motions easier and more varied. Hence, the bone in the tongue of birds, by diminishing its flexibility; the osseous scales of the swan's tongue, by reducing the extent of the sentient surface; the adhesion of the tongue to the jaws in frogs, in the salamander, and in the crocodile, by preventing freedom of motion,—render, in these animals, the sense of taste duller, and less calculated to feel the impression of sapid bodies, than in man and the other mammiferous animals. Man would, probably, excel all the other animals in delicacy of taste, if he did not at an early period impair its sensibility by strong drinks, and by the use of spices, and of all the luxuries that are daily brought to our tables. The quadrupeds, whose tongue is covered by a rougher skin, discover better than we can, by the sense of taste, poisonous or noxious substances. We know that in the great variety of plants which cover the face of the earth, herbivorous animals select a certain number suited to their nature, and uniformly reject those which would be injurious to them.

CXXIX.—Is the lingual branch of the fifth pair of nerves, alone subservient to the sense of taste? Are not the ninth pair (almost wholly distributed in the tissue of the tongue), and the glosso-pharyngeal branch of the eighth, likewise subservient to this function? Most anatomists, since Galen, have thought that the eighth and ninth pair supplied the tongue with its nerves of motion, and that it received from the fifth its nerves of sensation. Several filaments, however, of the great hypoglossal nerve may be traced into the nervous papillæ of the tongue. This nerve is larger than the lingual, and is more exclusively distributed to this organ than the fifth pair, to which the other nerve belongs. Hevermann states, that he knew a case in which the sense of taste was lost from the division of the nerve of the ninth pair, in removing a scirrhous gland. This case, however, appears to me a very suspicious one. The patient might still have tasted, by means of the lingual nerve, and the sense would only have been weakened. The division of one of the nerves of the ninth pair could render insensible only that half of the tongue to which it is distributed, the other half would continue fully to possess the faculty of taste.

The application of metals to the different nervous filaments distributed to the tongue, ought to inform us of their different uses, if, as Humboldt suspects, the galvanic excitement of the nerves of motion alone produces contractions. To ascertain the truth of this conjecture, I placed a plate of zinc within the skull, under the trunk of the nerve of the fifth pair, in a dog that had been killed a few minutes before, and that still retained its warmth: the muscles of the tongue, under which a piece of silver was placed, quivered very slightly; those of the forehead and temples in contact with the same metal experienced very sensible contractions whenever a communication was made by means of an iron rod. This experiment shewed that the lingual branch of this nerve was almost solely subservient to the sensation of taste,—which agrees with the opinion of most physiologists; and the same inference may be drawn from the anatomical knowledge of the situation of this nerve, which almost entirely terminates in the papillæ of the membrane of the tongue, and sends very few filaments to the muscles of that organ. But though the galvanic irritation applied to the hypoglossal nerve affected the whole tongue in a convulsive manner, I did not think myself justified to infer that this nerve was solely destined to perform its motions; as this nervous trunk might, in this part of the body, as it does in others, contain filaments both of sensation and motion.

The tongue, though an azygous organ, is composed of parts completely symmetrical; there are on each side four muscles, (*stylo*, *hyo*, *genio-glossal*,

and lingual); three nerves, (*lingual*, *glosso-pharyngeal*, *and hypoglossal*); a ranine artery and vein; and a set of lymphatic vessels precisely alike. All these parts, by their union, form a fleshy body of a close texture, and not easily unravelled, similar to that of the ventricles of the heart, endowed with a considerable degree of mobility, in consequence of the numerous vessels and nerves entering into its substance.* If we compare their number and size with the small bulk of the organ, it will be readily understood, that as no part of the body can execute more frequent, more extensive, and more varied motions, so no one receives more vessels and nerves. A middle line separates and marks the limits of the two halves of the tongue, which, anatomically and physiologically considered, appears formed of two distinct organs in juxta-position.

This independence of the two parts of the tongue is confirmed by the phenomena of disease: in hemiplegia, the side of the tongue corresponding to the half of the body that is paralysed, loses likewise the power of motion; the other retains its mobility, and draws the tongue towards that side. In carcinoma of the tongue, one side remains unaffected by the disease which destroys the other half: lastly, the arteries and nerves of the left side rarely anastomose with those on the right; injections forced along one of the ranine arteries, fill only the corresponding half of the organ, &c.

CXXX. *Of the organ of touch.*—No part of the surface of our body is exposed to receive the touch of a foreign body, without our being speedily informed of it. If the organs of sight, of hearing, of smell, and of taste, occupy only limited spaces,—touch resides in all the other parts, and effectually watches over our preservation. The touch, distributed over the whole surface, appears to be the elementary sense, and all the others are only modifications of it, accommodated to certain properties of bodies. All that is not light, sound, smell, or flavour, is appreciated by the touch, which thus instructs us in the greater part of the qualities of bodies which it concerns us to know, as their temperature, their consistence, their state of dryness or humidity, their figure, their size, their distance, &c. It corrects the errors of the sight, and of all the other senses, of which it may justly be called the regulator; and it furnishes us with the most exact and distinct ideas.

The touch, of which some authors have sought to consecrate the excellence, by giving it the name of the geometrical sense, is not, however, safe from all mistake. Whilst it is employed on the geometrical properties derived from space, and that it appreciates the length, the breadth, the thickness, the form of bodies,—it transmits to the intellect rigorous and mathematical results; but the ideas we acquire by its means, on the temperature of bodies, are far from being equally precise. For, if you have just touched ice, another body colder than yours will appear warm. It is for this reason that sub-

* Haller concluded that the tongue possesses irritability. Blumenbach has lately determined the point by direct experiment. He caused the tongue of a four-year-old ox, which had been killed in the usual way, to be cut out while the animal was yet warm, and at the same time the heart, in order that he might compare the oscillatory motions of both viscera; and when they were excited at the same time by mechanical stimuli, the tongue appeared to survive the heart by more than seven minutes; and so vivid were its movements, when cut across after its separation, that its motions might be compared to those of the tail of a mutilated snake. The same phenomenon was remarkable in the divided tongues of other animals, on the application of mechanical or chemical stimuli; and also in that of a boy, which had been bit off during a violent fit of epilepsy.

From this, it would appear that the account which Ovid gives of the cruel deed of Tereus is nearly correct:—

———— "Compressam forcipe linguam
Abstulit ense fero. Radix micat ultima linguæ,
Ipsa jacet, terræque tremens immurmurat atræ,
Utque salire solet mutilatæ cauda colubræ,
Palpitat, et moriens dominæ vestigia quærit."—*Metamor.* VI.—*J. C.*

terraneous places appear warm to us during winter. They have kept their temperature whilst all things else have changed theirs; and as we judge of the heat of an object by its relation not only to our own, but also to that of other bodies, and of the air about us, we find the same places warm which had appeared cold to us in the middle of summer.

The densest bodies being the best conductors of heat,* marble, metals, &c., appear colder to us than they really are, because they carry it off so rapidly. Marble and metals, when polished, appear still colder, because as they touch the skin in many more points at once, they effect this abstraction more effectually. Every one knows the experiment of placing a little ball between the two fingers crossed, and producing the sensation of two different balls.

CXXXI. *Of the integuments.*—The general covering of the whole body is the organ of touch, which resides in the skin properly so called. The cellular tissue, which connects together all our parts, forms over the whole body a layer, varying in thickness, which covers it in every part: it is called *panniculus adiposus*. As it approaches the surface, its laminæ are more condensed, are in more immediate contact with each other, and are no longer separated by adeps. It is by the closer juxta-position of the laminæ of the cellular tissue that the skin or dermis is formed,—a dense and elastic membrane, into which numerous vessels, of all kinds, are distributed, and into which so great a quantity of nerves terminate, that the ancients did not hesitate to consider the skin as purely nervous.

In certain parts of the body a very thin muscular plane separates the skin from the panniculus adiposus. This kind of panniculus carnosus envelopes, almost entirely, the body of some animals; its contractions wrinkle their skin covered with hairs, these rise, vibrate, and thus are cleared of the dust and dirt which may have gathered on them. It is by means of a cutaneous muscle, of very complex structure, that the hedge-hog is enabled to coil himself up, and to present to his enemy a surface studded with sharp points: only a few scattered rudiments of an analogous structure are to be met with in the human body; the occipito-frontalis, the corrugator supercilii, several muscles of the face, the platysma myoides, the palmaris cutaneus, may be considered as forming part of this muscle. We may even include the cremaster, whose expanded fibres, surrounded by the dartos, have misled some anatomists to such a degree that they have admitted the existence of a muscular texture in the latter. These fibres of the cremaster produce distinct motions in the skin of the scrotum, wrinkle it in a transverse direction, and at the same time bring up the testicles. The platysma myoides acts likewise on the skin of the neck: lastly, the occipito-frontalis in some men performs so distinct a motion of the hairy scalp, as to throw off a hat, a cap, or any other covering that may be on the head. One may compare to the panniculus carnosus, the muscular coat of the digestive tube situated throughout its whole length below the mucous membrane, which is merely a prolongation of the skin modified and softened.

But if in man the subcutaneous muscle, from its imperfect state, answers purposes only of secondary importance, the layer of cellular adipose sub-

* Woolly substances, &c. all felts, of which the crossing hairs confine, in some sort, a great quantity of air, a fluid which, from its gaseous state, is a very bad conductor of heat, retain heat well; and, being of equal thickness, a stuff of fine wool, of which the hairs are more separated and the tissue softer, will be warmer than a stuff of coarse wool, of which the threads, too close, form a dense body, through which cold, as well as heat, will pass with ease. It is by thus confining a certain mass of air that snow keeps the soil it covers in a mild temperature, and preserves plants from the injury of excessive cold;—a physical truth which is found figuratively expressed in the words of the Psalmist, "*Et dedit illi nivem tanquam vestimentum.*"

stance, extended under the skin, gives to the latter its tension, its whiteness, its polish, its suppleness, favours its applying itself to tangible objects, and thus renders the touch more delicate. Too hard or wrinkled a skin would have applied itself in a very incomplete manner to bodies of a small size, and would not readily have accommodated itself to the small irregularities of those of inconsiderable bulk. Hence, the pulp of the fingers, which is the seat of a more delicate touch, is furnished with a kind of adipose cushion supported by the nails, ready to be applied to polished surfaces, and to discover the slightest asperities. I have observed the sense of touch to be very imperfect in men wasted by marasmus, and whose hard, dry, and wrinkled skin adheres, in certain situations, to the subjacent parts.

The chemical analysis of the cutaneous tissue shews that it does not exactly resemble that of the cellular and membranous tissue; it is gelatino-fibrous, and, with regard to its structure and to its share of contractility, it occupies a medium between the cellular tissues and the muscular flesh.* There arise from the surface of the skin innumerable small papillæ, fungous, conical, pointed, obtuse, and variously shaped, in the different parts of the body. These papillæ are merely the pulpous extremities of the nerves which terminate into them, and around which there are distributed vascular tissues, of the utmost minuteness. The papillæ of the skin, which are more distinct in the fingers and lips than elsewhere, swell when irritated, and elevate in a manner the epidermis; and this kind of erection, which is useful when we wish to touch a substance with great precision, may be excited by friction, or by moderate heat.

The nervous or sentient surface of the skin is covered with a mucous coating, colourless in Europeans—blackened, from the effects of light, among the natives of southern climates; of a gelatinous nature, destined to maintain the papillæ in that state of moisture and softness favourable to the sense of touch. This mucilaginous layer, known under the name of *rete mucosum* of Malpighi, seems to contain the principle which causes the variety of colour in the skin of different nations, as will be observed in speaking of the varieties of the human species.

The reticular state of the rete mucosum may be explained in two ways: a thin and gelatinous layer, extended on the papillar surface of the skin, is perforated at each nervous papilla, and if it were possible to coagulate or to detach this coating, we should have a real sieve or reticulated mesh-work, with a perforation at every point, corresponding to a cutaneous papilla. The sanguineous and lymphatic capillaries which surround the nervous papillæ, form, besides, by their connexions, a net-work, the meshes of which are very minute, and adhere to the epidermis by a multitude of small vascular filaments, that insinuate themselves between the scales of this last envelope, and terminate in exhaling or absorbing pores, according as they belong to the arterial capillaries or to the lymphatic absorbents. It is sufficient, indeed, to remove gently the scales of the epidermis, in order to bare their orifices, and procure the absorption of any virus. It is the net-work of Malpighi, or rather this assemblage of interlaced capillary vessels below the epidermis, which appears to be the seat of the primary phenomena in the majority of cutaneous inflammations and eruptive diseases.

The skin would be unable to perform its functions, if an outer, thin, and transparent membrane, the *epidermis*, did not prevent it from being over-dried. This superficial covering is quite insensible; no nerves, and no vessels of any kind, are found in it; and even in the present state of the science, we

* See the chapter in the APPENDIX, on the Chemical Constitution of the Animal Textures and Secretions.

do not understand how it is formed, or how it repairs and reproduces itself when destroyed. The most minute researches on its structure merely shew the existence of an infinite number of lamellæ, overlapping each other, like the tiles of a roof. This *imbrication* of the epidermoid lamellæ is very obvious in fishes and reptiles; the scaly skin of which is merely an epidermis whose parts are much more coarsely shaped.

It was observed (XLII.) in the account of absorption, how much friction facilitates the absorption of substances applied to the surface of the skin, by raising the scales of the epidermis so as to expose the orifices of the absorbents, whose activity it in other respects increases.

Haller conceives that the epidermis is formed by the drying up of the outer layers of the rete mucosum. Morgagni thinks it is formed by the induration of the skin, in consequence of the pressure of the atmosphere. In objection to these hypotheses, one may inquire how it happens, that by the time the fœtus, immersed in the liquor amnii, has attained its third month, it is covered with such an envelope.* Pressure renders the skin hard and callous, increases considerably its thickness, as we see in the soles of the feet and in the palms of the hands of persons engaged in laborious employments. The epidermis reproduces itself with an incredible rapidity, after falling off in scales, after erysipelas or herpetic eruptions; or, when removed in large flakes by blistering, it is renewed in the course of a very few days. The cuticle, together with the hairs and nails, which may be considered as productions of the same substance, are the only parts in man that are capable of reproducing themselves. The hairs and the horns of quadrupeds, the feathers of birds, the calcareous matter of the lobster and of several molusca, the shell of the turtle, the solid sheaths of a number of insects, possess, as well as the epidermis, this singular property. In other respects the chemical structure of all these parts is the same; they all contain a considerable proportion of phosphate of lime, withstand decomposition, and give out a considerable quantity of ammonia on being exposed to heat. The use of the epidermis is to cover the nervous papillæ, in which the faculty of the touch essentially resides, to moderate the too vivid impression that would have been produced by an immediate contact, and to prevent the air from drying the skin or from impairing its sensibility.

This dessication of the cutaneous tissue is further prevented, and its suppleness maintained, by an oily substance which exudes through its pores, and is apparently secreted by the cutaneous exhalants. This unctuous liniment should not be mistaken for that which is furnished by the sebaceous glands in certain situations, as around the nostrils, in the hollow of the arm-pits, and in the groins. This adipose substance with which the skin is anointed, is abundant and fetid in some persons, especially in those of a bilious temperament, with red hair. It is likewise more copious in the African negroes, as if Nature had been anxious to guard against the too rapid dessication, by the burning atmosphere of tropical climates. This use of the oil of the skin is likewise answered by the tallow, the fat, and the disgusting substances with which the Caffres and the Hottentots anoint their body, in the manner described under the name of tatooing by the travellers† who have penetrated into the interior of the burning regions of Africa.

* The epidermis seems to be formed from a certain *dry* secretion, of which the skin is the organ. The exhalants, with which the dermal tissue is abundantly supplied, allow a viscus and albuminous fluid to escape, which contains a great proportion of phosphate of lime; thus an envelope is formed analogous to the shell which covers the egg. The epidermis may, therefore, be considered as a kind of excremental tissue—as a residue or product of nutrition thrown on the surface of the body, and forming a useful and requisite protection to the economy of organized beings.

† Among others, Kolben, *Description du Cap*

The ancients had a somewhat similar practice; and the anointing with oil, so frequently used in ancient Rome, answered the same purpose of softening the skin, of preventing its becoming dry or chapped.* The pomatums employed at the present day at the toilet possess the same advantages. The continual transudation of this animal oil renders it necessary, occasionally, to clean the skin by bathing; the water removes the dust and the other impurities which may be attached to its surface by the fluid which lubricates it. It is this humour wh ch soils our linen, and obliges us so frequently to renew that in immediate contact with the skin, and which makes the water collect in drops when we come out of the bath, &c.

Though the parts in which there is found the greatest quantity of subcutaneous fat are not always the most oily, and though one cannot consider this secretion as a mere filtration of this adeps through the tissue of the skin; corpulence has, however, a manifest influence on its quantity. I know several very corpulent persons in whom it appears to be evacuated by perspiration, on their being heated by the slightest exertion. They all grease their linen in less than twenty-four hours. An excess of the oily matter of perspiration is injurious, by preventing the evacuation of the perspiration, and its solution in the atmosphere.

We all know how, after the epidermis has been removed, the slightest contact is painful; that of the air is sufficient to bring on a painful inflammation of the skin, exposed by the application of a blister. The epidermis, as was likewise mentioned in speaking of the absorption, placed on the limits of the animal economy, and in a manner inorganic, serves to prevent heterogeneous substances from being too readily admitted into the body, and, at the same time, it lessens the too vivid action of external objects on our organs. All organised and living bodies are furnished with this covering; and in all, in the seed of a plant, in its stem, and on the surface of the body in man and animals, it bears to the skin the greatest analogy of function and nature. Incorruptibility is in a manner its essence, and is its peculiar character; and in tombs, which contain merely the dust of the skeleton, it is not uncommon to find whole, and in a state to be readily distinguished, the thickened epidermis that forms the sole of the foot, and especially the heel. However, this incorruptibility is possessed, as well as others of the qualities of the skin, by the nails and the hairs, which may be considered as its appendages.

CXXXII. *Of the nails.*—The nails are, in fact, only a part of the epidermis; they are continuous with it, and after death fall off along with it. They are thicker and harder; like it they are inorganic and lamellated; they grow rapidly from their root towards their free extremity; they reproduce themselves rapidly, and acquire several inches in length, when the part beyond the ends of the fingers and toes has not been removed; as is the case with the Indian fakirs. In this state of development they bend over the tips of the fingers and toes, and impair the sense of touch, whose free enjoyment is preferable to any advantages which savages can derive from their long and crooked nails, in defending themselves, or in attacking animals, or tearing to pieces those which they have killed in hunting. The nails are quite insensible, and the reason that so much pain is felt when the nails run into the flesh, and that the operation of tearing them out, which is sometimes necessary, is so painful, is, that the nerves over which the nail grows are more or less injured when it grows in a wrong direction. The pain from the growing

de Bonne-Espérance. Sparrmann, *Voyage au Cap de Bonne-Espérance et chez les Hottentots.* Vaillant, *Voyage dans l'Intérieur de l'Afrique.*

* The reply of the old soldier is well known, who, on being asked by Augustus how he came to live so long, said he owed his long life to the use of wine inwardly, and to that of oil outwardly: *intus vino, extus oleo*

of the nails into the quick, is no proof of their being sentient; any more than the growth of corns proves the sensibility of the epidermis, of which they are but thickened parts, become hard and callous by pressure, and which, confined in tight shoes, press painfully on the nerves below. The nail itself may acquire a considerable degree of thickness; I have seen that of the great toe nearly half an inch thick. The use of the nails is to support the tips of the fingers, when they are applied to unyielding substances; they likewise concur in improving the mechanism of the touch.*

CXXXIII. *Of the hair on the head and other parts of the body.*—These parts are treated of in the present instance, only in consequence of their connexion with the epidermis; as, far from improving the touch, they interfere with it, or at least render it less delicate.

The skin in man is more bare than that of other animals; it is likewise least covered with insensible parts that might blunt the sense of touch. In almost all mammiferous animals the whole body is covered with hair; only a small part of the human body has any hair on it, and that in too small a quantity, and of too delicate a texture, to interfere with the touch. Some men, however, have a very hairy skin, and I have seen several who, when naked, looked as if covered over with the skin of an animal, so great was the quantity of hair over the whole body, of which no part was bare but a small portion of the face, the palms of the hands, and the soles of the feet. This extraordinary growth of hair is in general a sure sign of vigour and strength. In childhood, there is no hair except on the head, the rest of the body is covered with down. Women have no beard, and there is in them a smaller quantity of hair in the arm-pits and on the parts of generation, and scarcely any on the limbs and trunk. But as though the matter which should provide for the growth of the hair were wholly applied to the hairy scalp, it is observed, that the hair of their head is longer and in greater quantity.

The colour of the hair varies from white to jet black; and, as will be mentioned in speaking of the temperaments and of the varieties of the human species, this difference of colour is a test by which we judge of those varieties. The colour of the hairs enables us to judge of their thickness: Withof, who, with a truly German patience, was at the pains to count how many hairs were contained in the space of a square inch, states, in his dissertation on the human hair, that there are five hundred and seventy two black hairs, six hundred and eight chestnut, and seven hundred and ninety light coloured; so that the diameter of a hair, which is between the three and seven hundredth part of an inch, is least in light hair, and these are the finer the lighter their shade. It is likewise observed, that men of a bilious constitution, with dark hair, and inhabiting warm climates, have more hair in other parts of the body, and that it is coarser and more greasy.

In whatever part of the body hairs may grow, they are every where of the same structure, they all arise from a vesicular bulb in the adipose cellular tissue: from this bulb, containing a gelatinous lymph, on which the hair

* The toe-nails are favourable to the laying the foot to the surface on which the body is supported; they likewise improve the sense of touch in this part. The use of the feet is not merely to support the weight of the body; they are also intended to guide us in feeling for the plane on which we are to rest them, to enable us to judge of the solidity, of the temperature, and of the inequalities of the ground on which we tread. They, therefore, required rather a delicate sense of touch. The division of the fore part of the foot into several distinct and separate parts, serves to enable us to stand more firmly, and facilitates the action of walking. I have seen several soldiers who lost, from severe cold, the extremities of their feet, in crossing the Alps which separate France from Italy. Those who had lost only their toes, did not walk so steadily, and frequently fell in treading on uneven ground. Those who had lost one half of their feet were obliged to use crutches.

seems to be nourished, the latter, at first divided into two or three filaments which constitute a kind of root, comes out in a single trunk, passes through the skin and epidermis, receiving from the latter a sheath that covers it to its extremity, which terminates in a point.

A hair may therefore be considered as an epidermoid tube, filled with a peculiar kind of marrow. This spongy stem, which forms the centre of a hair, is a more essential part of it than the sheath supplied by the epidermis. Along this spongy and cellular filament, the animal oil of the hair and the juices on which it is repaired flow. Though we see, in some animals, vascular branches and very small nervous filaments directed towards the root of certain kinds of hair, and lost in it, as is the case with the long and stiff whiskers of some of the quadrupeds,—it is impossible to say, whether in man the hair or its bulbs receives vessels and nerves. Is the human hair nourished by the imbibition of the gelatinous fluid contained in its bulb, or is it nourished on the fat in which the latter is imbedded? Are vessels distributed along their axis, from the root to the extremity? In favour of this opinion, it was usual to mention the bleeding from the hair when cut, in the disease called *plica Polonica*. But this disease, lately observed in Poland by the French physicians, appeared to them a mere entangling of hair, in consequence of the filth of the Poles, and of their habit of keeping their head constantly covered with a woollen cap. The hairy scalp remains perfectly sound beneath the entangled hair, and the only way to cure the complaint is to cut off the hair. Fourcroy* thinks that each hair has several short branches that stand off from it, which, according to the explanation given by Monge, favour the matting of the hairs that are to be converted into tissues, by the process called felting.

CXXXIV.—Among the most remarkable qualities of the hair one may take notice of the manner in which it is affected by damp air, which, by relaxing its substance, increases its length. It is on that account that hairs are used for the construction of the best hygrometers. Nor must we omit either the readiness with which they grow and are reproduced, even after being plucked out by the roots, as I have often seen after the cure of tinea by a painful method: nor their insulating property with respect to the electric fluid, of which they are very bad conductors; a remarkable property, viewed with reference to the conjectured nature of the nervous fluid.

The hairs possess no power of spontaneous motion by which they can rise on the head, when the soul shudders with horror or fear; but they do bristle at those times, by the contraction of the occipito-frontalis, which, intimately adhering to the hairy scalp, carries it along in all its motions.

They appear totally without sensibility; nevertheless, the passions have over them such influence that the heads of young people have turned white the night before execution. The Revolution, which produced in abundance the extremes of human suffering, furnished many authentic instances of persons that grew hoary in the space of a few days. In this premature hoariness, is the hair dried up, as in old people, when it seems to die for want of moisture and its natural juices?

The following fact seems to shew that they are the excretory organ of some principle, the retention of which might be of very injurious consequence. A chartreux, who every month had his head shaved, according to the rule of his order, quitting it at its destruction, went into the army, and let his hair grow. After a few months, he was attacked with excruciating headaches, which nothing relieved. At last, some one advised him to resume his old

* *Système des Connoissances Chimiques*, tome ix. p. 263

habit, and to have his head frequently shaved; the headaches went off, and never returned.

We know, says Grimaud,* that there are nervous headaches, which give way to frequent cropping the hair:—when it is kept close cut, the more active growth that takes place sets in motion stagnating juices. A friend of Valsalva, as Morgagni † relates, dispelled a maniacal affection, by having the head of the patient shaved; Casimir Medicus cured obstinate gonorrhœa, by the frequent shaving of the parts of generation.

The hairs partake of the inalterability, the almost indestructibility of the epidermis. Like it, they burn with a fizzing, and give out in abundance a fetid ammoniacal oil. The ashes that remain from burning them contain much phosphate of lime.‡ The horns of mammiferæ, the feathers of birds, give out the same smell in burning, and yield the same products as the hair on the head and other parts; which has led to the saying that these last were a sort of horny substance, drawn out like wire. Acids, but especially alkalies, dissolve them: accordingly, all nations that cut the beard, first soften it, by rubbing it with alkaline and soapy solutions.

Is the use of the hair to evacuate the superabundant nutritious matter? The epoch of puberty and of the termination of growth, is that in which it first springs, in many parts of the body which were before without it. They are, at the same time, the emunctory by which nature gets rid of the phosphate of lime, which is the residue of the work of nutrition. The hairs of quadrupeds, whose urine abounds less in phosphoric salts than that of man, seem especially to fulfil this destination. The hairs have some analogy with the fat, which has not yet been ascertained. They are often found accidentally developed in the fatty tumours known under the name of steatomas. Finally, they have uses relative to the parts on which they grow.

CXXXV. *Of the sense of touch, &c.*—The faculty of taking cognizance of tangible qualities belongs to all parts of the cutaneous organ. We have only to apply a substance to any part of the surface of our body, to acquire the idea of its temperature, of its dryness or moisture, of its weight, its consistence, and even its particular figure. But no part is better fitted to acquire exact notions on all these properties, than *the hand*, which has ever been considered as the especial organ of touch. The great number of bones that form its structure, make it susceptible of very various motion, by which it changes its form, adapts itself to the inequalities of the surfaces of bodies, and exactly embraces them: this apt conformation is particularly manifest at the extremities of the fingers. Their anterior part, which is endued with the most delicate feeling, receives, from the medium and cubital nerves, branches of some size, which end in rounded extremities, close, and surrounded with a cellular tissue. The part of the fingers which is called their pulp, is supported by the nails; vessels in great number are spread through this nervo-cellular tissue, and moisten it with abundant juices, that keep up its suppleness. When perspiration is increased, it breaks out in small drops over this extremity of the fingers, along the hollow of the concentric lines with which the epidermis is furrowed.

It has been attempted to explain the pleasure we feel in touching rounded and smooth surfaces, by shewing that the reciprocal configuration of the hand and of the body to which it is applied, is such, that they touch in the greatest number of points possible. The delicacy of the touch is kept up by the fineness of the epidermis: it increases by education, which has more power over this sense than over any of the others. It is known with what

* *Second Memoir on Nutrition*, p. 49.

† *De Sedibus et Causis*, Epist. 8. No. 7

‡ See the Chapter in the APPENDIX, on the Chemical Constitution of the Textures, &c.

eagerness a child, allowed the free use of his limbs, stretches his little hands to all the objects within his reach, what pleasure he seems to take in touching them in all their parts, and running over all their surfaces. Blind men have been known to distinguish by touch the different colours, and even their different shades. As the difference of colour depends on the disposition, the arrangement, and number of the little inequalities which roughen the surface of bodies that appear the most polished, and fit them to reflect such or such a ray of light, absorbing all the others, one does not refuse to believe facts of this kind, related by Boyle, and other natural philosophers.

Some parts appear endowed with a peculiar touch; such are the lips, whose tissue swells and spreads out under a voluptuous contact; a vital turgescence, explicable without the supposition of a spongy tissue in their structure,—such are those organs which Buffon considers as the seat of a sixth sense. In most animals, the lips, and especially the lower one, without feathers, scales, or hair, are the organ of a sort of touch, imperfect at best. When the domestic quadrupeds, such as the horse, the dog, the ox, &c. want to judge of the tangible qualities of bodies, you will see them apply to it the end of their nose, the only part where the external covering is without hair; the fleshy appendages of certain birds, and many fish; the antennæ of butterflies, always set near the opening of the mouth, answer the same purpose. The tail of the beaver, the trunk of the elephant, are, in like manner, the parts of their body where touch is most delicate. Observe that the perfection of the organ of touch insures to these two animals a degree of intelligence allotted to no other quadruped, and becomes, perhaps, the principle of their sociability. The books of travellers and naturalists swarm with facts attesting the wonderful sagacity of the elephant. Some Indian philosophers have gone the length of allowing him an immortal soul. If birds, notwithstanding the prodigious activity of their life of nutrition, are yet of such confined intelligence, so little susceptible of durable attachment, so restive to education, is not the cause to be assigned to their imperfection of touch? In vain the heart sends towards all their organs, with more force and velocity than in any other animal, a warmer blood, and endued more remarkably with all the qualities which characterise arterial blood; in vain is their digestion rapid, their muscular power lively and capable of long-continued motion, and certain of their senses, as those of sight and hearing, happily disposed;—touch being almost nothing with them, as also the greater number of impressions belonging to this sense, which informs us of the greater part of the properties of bodies, the circle of their ideas must be extremely narrow, and their habits and manners much more remote than those of quadrupeds from the habits and manners of man.

CXXXVI.—Of all the senses the touch is the most generally diffused among animals. All possess it,—from man, who in the perfection of this sense excels all vertebral animals, to the polypus, who, confined to the sense of touch only, has it in such delicacy, that he appears, to use a happy expression of M. Duméril, to feel even light. The skin of man is more delicate, fuller of nerves than that of the other mammiferæ; its surface is covered only by the epidermis, insensible indeed, but so thin that it does not intercept sensation, whilst the hairs which cover so thickly the body of quadrupeds, the feathers which clothe that of birds, quite deaden it. The hand of man, that admirable instrument of his intelligence, of which the structure has appeared to some philosophers* to explain sufficiently his superiority over all living species; the hand of man naked, and divided into many movable

* See the work of Galen, *de Usu Partium*, cap. iv. v. vi.; and Buffon, *Histoire Naturelle*, tom. iv. et v. 12mo.

parts, capable of changing every moment its form, of exactly embracing the surface of bodies, is much fitter for ascertaining their tangible qualities than the foot of the quadruped, enclosed in a horny substance, or than that of the bird, covered with scales too thick not to blunt all sensation.

CXXXVII. *Of the nerves.*—These whitish cords, which arise from the base of the brain and from the medulla oblongata, are distributed to all parts of the body, and give them at once the power of moving and feeling. In this analysis of the functions of the nervous system, the most natural order is to consider them merely as conductors of the power of sensation. We shall then see in what manner they transmit the principle of motion to the organs by which it is performed. The nerves arise* from all sentient parts, by extremities that are in general soft and pulpy, but not alike in all in consistence and form; and it is to these varieties of arrangement and structure, that the varieties of sensation in the different organs are to be referred.

One may say, that there exists in the organs of sense a certain relation between the softness of the nervous extremity and the nature of the bodies which produce an impression upon it. Thus, the almost fluid state of the retina bears an evident relation to the subtilty of light. The contact of this fluid could not produce a sufficient impression unless the sentient part were capable of being set in motion by the slightest impression. The portio mollis of the seventh pair, wholly deprived of its solid covering, and reduced to its medullary pulp, readily partakes in the sonorous motions transmitted to it by the fluid, in the midst of which its filaments are immersed. The nerves of smell and of taste are more exposed than the nervous papillæ of the skin which are employed in receiving the impressions produced by the coarser properties of bodies, &c.

From their origin the nerves ascend towards the medulla oblongata and the spinal marrow, in a line nearly straight, and seldom tortuous, as most of the vessels. When they have reached these parts they terminate in them, and are lost in their substance, as will be mentioned in speaking of the structure of these nervous cords.

CXXXVIII. *Structure of nerves.*—Every nerve is formed of a great number of filaments, extremely delicate, and which have two extremities, the one in the brain, and the other from the part into which they terminate, or from which they originate. Each of these nervous fibres, however minute, is composed of a membranous tube, which is a production of the pia mater. Within the parietes of this tube there are distributed innumerable vessels of extreme minuteness; it is filled within with a whitish marrow, a kind of pulp, which Riel states he insulated from the small canal containing it, by concreting it by means of the nitric acid, which dissolves the membranous sheath, and leaves uncovered the medullary pulp, forming the essential part or basis of the nervous filament. The same physiologist discovered by a different process the internal structure of each nervous fibrilla: he dissolved the whitish or pulpy part by a long-continued solution in alkaline ley, and he succeeded thus in separating it from the membranous tube which enclosed it, and which was emptied. The membranous sheath is of cellular structure, and is remarkable only by its consistence, and by the very considerable num-

* In considering the nerves as conductors of sensation, it is correct to say, that they arise from sentient parts, since it is the extremity most distant from the brain which experiences the *sensitive impression* that is propagated to the organ itself along the course of the nerve. In attending, on the contrary, to the phenomena of motion, the nerves are considered to arise from the brain; for it is from the centre to the circumference that the principle of motion is transmitted to the muscles called by Cullen *moving extremities of the nerves*. Some anatomists have thought it a doubtful point, whether the nerves arise from the brain and spinal marrow, or whether these parts are formed by the union of the nerves.

ber of vessels of all kinds that are distributed to its parietes; it ceases to cover the nerves near their two extremities, and protects them only along their course.

Each nervous fibre, thus formed of two very distinct parts, joins other fibres of a perfectly similar structure, to form a nervous filament enveloped in a common sheath of cellular tissue. These filaments by their union form small ramifications, and these progressively larger branches, and lastly trunks, wrapped in a common covering of cellular tissue; then other envelopes to each fasciculus of filaments, and lastly, a sheath to each individual filament. When nervous cords are of a certain size, veins and arteries of a pretty considerable calibre may be seen to insinuate themselves between the bundles of fibres of which they are composed; these vessels then divide, after penetrating among them, and furnish the capillary ramifications which are distributed to the parietes of the sheath common to each filament. These small vessels, according to Reil, allow the nervous substance to exhale into each membranous tube; this likewise becomes the secretory organ of the medulla, with which it is filled.

CXXXIX. *Distribution of nerves.*—The nervous filaments unite, or are separated from one another, but do not run into each other. The divisions of the nerves are different from those of the arteries, and their mode of junction does not admit of being compared to that of the veins. It is, in the first instance, a mere separation; in the second, an approximation of filaments which had been separated, and which, though united in common sheaths, have, nevertheless, each a proper covering, are merely in juxta-position, and perfectly distinct. If that were not the case, one could not say that each fibre has one extremity in the brain, and the other in some one point of the body; nor could one conceive how the impressions which several sentient extremities receive at once, reach the brain without running into each other; nor in what manner the principle of motion could be directed towards a single muscle receiving its nerves from the same trunk as the other muscles of the limb.

We may admit the existence of four kinds of nerves: 1st, those having double roots, as the spinal nerves, the sub-occipital, and the trigeminal or the fifth pair of cranial nerves,—one of these roots being subservient to voluntary motion, whilst the other is a conductor of sensibility, as the anterior and posterior roots of the spinal nerves; 2dly, nerves having a single root or origin, as the first, second, third, fourth, sixth, the *portio mollis* of the seventh, and the ninth pairs,—nerves which are exclusively subservient either to sensation, as the olfactory, optic, and auditory nerves, or to the motion of the muscles which they supply, as the third, fourth, sixth, and ninth pairs; 3dly, the respiratory nerves, which have been called by Mr. Bell also the superadded, and which consist in the *portio dura* of the seventh pair, the eighth or pneumogastric, which may be considered as the centre of this class of nerves, the glasso-pharyngian, the spinal or accessory of Willis, and the diaphragmatic or external thoracic: all these nerves proceed from the lateral columns of the superior portion of the medulla oblongata, and are destined to preside over the organs concerned in respiration; 4thly, the sympathetic order of nerves, which communicate with all the spinal nerves.

It is by thus distributing the nerves in four divisions, that we are enabled to form an accurate conception of the particular functions of this very complicated and difficult part of the animal economy, and to ascertain that sensation and motion have, in the first and second classes, peculiar and distinct agents, whilst the third and fourth divisions serve to associate, by more or less intimate connexions, the most important functions of our economy. The

earlier anatomists seem to have had some idea of this important distinction, since they applied the terms of middle and little sympathetics to the eighth pair, and the portio dura of the seventh.

In general, the nerves divide from each other, and unite at an angle more or less acute, and equally favourable to the circulation of a fluid, from the circumference to the centre, and from the centre to the circumference.

The structure of the nerves is different according to their situation. Thus, the medullary fibres of the optic nerve are not provided with membranous coverings, the pia mater alone furnishing a sheath to the cord formed by the union of these filaments ; the dura mater adds a second coat to it on its leaving the skull. This coat, belonging likewise to the whole nerve, is not continued over it after it has entered the eye-ball, and is lost in the sclerotica. A minute artery passes through the centre of the optic nerve, and then dividing, forms a rete mirabile, which supports the medullary pulp of the retina. The nerves which pass along osseous canals, as the Vidian nerve of the fifth pair, are not provided with a cellular covering, and their consistence is always greater than that of the nerves which are surrounded by soft parts.

CXL.—On reaching the brain, the medulla oblongata, or the spinal marrow, every nervous filament, as was already mentioned, parts with its membranous covering, which is lost in the pia mater, or immediate covering of these central parts of the brain. The medullary or white part of the brain is continued into their substance, which may be considered as principally formed by the assemblage of these nervous extremities, which it is difficult to distinguish in its tissue, from its want of consistence. It has long been known, that the origin of the nerves is not the spot at which they are detached from the brain, that they sink into the substance of this viscus, in which their fibres cross each other, so that those on the right pass to the left, and *vice versâ*. Soëmmering thought that the roots of the nerves, especially of the nerves of the organs of sense, reached to the prominences in the parietes of the ventricles of the brain, and that their furthest extremity was moistened by the serosity which keeps these inward surfaces in contact. It has likewise long been thought, that the cerebral extremities or the nerves all joined in a fixed point of the brain, and that to this central point all sensations were carried, and that from it all the determinations producing voluntary motion arose. But the inquiries of Gall on the structure of the brain and nervous system have completely overset these various hypotheses.

The spinal marrow and the nerves, in the different animals furnished with them, are larger in proportion to the brain, according as the animal is more distant from man in the scale of animation. In carnivorous animals the prodigious developement of the muscles required nerves of motion of a proportionate size ; hence in them the cerebral mass, compared to the nerves and spinal marrow, is very inconsiderable. It is observed that there exists the same relation in men of an athletic disposition ; the whole nervous power seems employed in moving their large muscles ; and the nerves, though very small in proportion to the rest of the body, are, however, very large, if compared to the cerebral organ. In children, in women, and in individuals possessed of much sensibility, the nerves are very large in proportion to the other parts of the body ; they decrease in size and shrink in persons advanced in years ; the cellular tissue which surrounds them becomes more consistent, adheres to them more closely, and there exists a certain analogy between the nerves of old men, enveloped by that yellowish tissue which makes their dissection laborious, and the branches of an old tree covered over by a destructive moss.

As the uses of the nerves cannot be explained independently of those of the brain, I shall now go on to consider this important viscus.

CXLI. *Of the spinal cord and its functions.*—This part of the nervous system ought no more to be called the spinal prolongation of the encephalon, as it has been by some writers, than it ought to be named the spinal marrow; both designations are equally erroneous. It is independent of the encephalic organ. As the central portion of the nervous system, it is to be found in many animals which possess no brain, and its volume is not proportionate to that of this organ. The ox, horse, and sheep, for example, which have smaller brains than man, have a much larger spinal cord. It is found in acephalous fœtuses, where the brain never existed. This latter organ appears to be superadded to it, and that only in the perfect animals, its proportionate size being always in an inverse ratio to the spinal cord. This part of the nervous system cannot, therefore, be considered as a production from the brain, and as formed by a collection of nerves which successively detach themselves from it. Its volume does not gradually diminish, owing to the nerves which it sends off; and instead of presenting the characters of a cord, which gradually decreases in thickness as it advances from the brain, it consists of a set of knots, bulbs, or separate prominences, equal in number to the pairs of nerves which arise from it. Finally, the spinal marrow is formed in the fœtus before either cerebellum or cerebrum; these organs proceeding from it, and not it from them. About the second month of the fœtal existence, the first epoch at which the brain can be rendered apparent by the action of alcohol, this organ is uncommonly small in proportion to the size of the spinal marrow, and arises evidently from a prolongation of the pyramidal eminences and the corpora olivaria. The different parts of the encephalic mass are gradually formed by the successive developement of the corpora pyramidalia, and it is only towards the end of gestation that the hemispheres are fully formed.*

The special functions that may be assigned to the spinal cord are different from those performed by the brain. In the spinal marrow resides the source of all the movements, both voluntary and involuntary, that are performed by the animal economy: it presides over those of the heart, of all the muscles of the interior life, as well as over those of the locomotive apparatus; and while the brain, reserved for the most noble and most important functions, seems exclusively charged with the operations of intelligence and thought, the spinal marrow holds under its controul all the contractile organs, and it is by its influence that all their contractions are executed.†

Thomas Bartholin had already acknowledged that the brain was more particularly the organ of sensation, and the spinal marrow that of motion.‡ He was equally sensible, that the best way of proceeding in the dissection of the brain, was to advance from the base to the vertex, and not from the summit to the base, as was the custom until our own times.

If we take a view of the graduated scale of the animal creation, says Dr. Gall, in his *Researches on the Nervous System*, &c. the sensible substance, which is merely a gelatinous pulp in the polypus, gradually becomes disposed into nervous filaments and cords in the more perfect animals. In order to establish a more extended intercourse with the external world, Nature has added more complex organs, according as the relations of the species with the surrounding creation become more numerous: it is thus that, by the successive addition of new organs, and the perfection of others, that the animal creation is elevated to man himself.

* See Appendix, Note G G.

† See Appendix, Note G G.

‡ "Et id quidem manifestius fit inspicientibus anatomen piscium; ibi enim medullæ caput et cauda insignis est magnitudinis; processus verò medullæ ad cerebrum admodum exiguum; cujus rei causa est, quòd pisces motu magis quàm sensu utantur, ac sic ad sensum plus conferat cerebrum vel cortex, ad motum plus medulla ipsa."—*Anatomia.*

The brain, a simple tubercle added to the anterior extremity of the spinal marrow, of which it seems to be nothing else than an accessory part, an appendix, in the insects, because amongst them it is but little larger that one of their numerous ganglions, becomes more complex and more perfect in the higher animals : in the fishes it but little exceeds the spinal cord ; whilst in the mammalia it possesses the same parts as in man, it is disposed nearly in the same form ; but in no animal is the double appearance of diverging and converging fibres better developed than in him ; in no other animal is the brain properly so called, that is to say, the superior part of the encephalon, or the hemispheres, possessed of a greater volume in proportion to the size of the animal.* The brain proper seems to be the seat of the nobler functions of intelligence ; whilst in the cerebellum, the medulla oblongata, and the spinal cord, appear to reside those faculties and manifestations that are common to us and the lower animals.

The nervous system ought not, therefore, to be compared to a tree, the trunk of which, represented by the spinal marrow, has its roots in the brain, and expands its branches through all parts of the body ; but ought rather to be considered as a net-work, whose threads communicate with each other, separate, re-unite, and join several masses or dilatations of greater or less size ; these masses or ganglions ought to be viewed as being the centres of communication.

The brain should not be considered as a ganglion, or even as a collection of ganglions, as the common ganglion of the nerves of the cranium, as some physiologists have done: the nerves which detach themselves from its base, or from the medulla oblongata, have their origins distinct from its substance. Their volume has no relation to its bulk, but is proportionate to the perfection of the different senses in the various species of animals ; thus, the olfactory nerve, which is very large in the mole, is small in the eagle ; while the optic nerve is, on the contrary, largely developed in the latter.

The spinal marrow may be considered as a series of ganglions, communicating with each other and with the brain.† These ganglions are of a size proportioned to that of the nerves which originate from them. It is owing to this that the spinal marrow is thicker towards the inferior part of the cervical and dorsal regions than in other portions of its length. Can the vertebral column be compared to a galvanic pile, of which the spinal cord is the conductor, and of which the brain and the parts of generation form the two extremities, occupying, and as if constituting, the two extremities of this kind of electro-motive apparatus ? Observation establishes, it may be said, a sort of antagonism between these two organs. Is there any analogous opposition existing between the cerebral nervous system and that which forms the grand sympathetic nerves ? We have formerly remarked, more than once, how ill-founded this attempt at identifying the vital phenomena with those of electricity appears to us. The communication of the spinal marrow with the brain is established by the medium of a double bundle of fibres, which, crossing each other, form the *corpora pyramidalia*, and direct themselves towards the brain, where we shall find them again, when the structure of this viscus comes under consideration.

CXLII. *Of the coverings of the brain.*—If it be true that one may judge of the importance of an organ by the care which Nature has taken to protect it from external injury, no organ will appear of greater importance than the brain, for no one appears to have been protected with greater care. The substance of this viscus has so little consistence, that the slightest injury would have altered its structure, and deranged its action ; hence it is powerfully

* See APPENDIX, Note G G. † See APPENDIX, Note G G.

guarded by several envelopes, the most solid of which is the bony case in which it is contained.

No part of anatomy is better understood than that of the many bones which, by their union, form the different parts of the human head. Every thing that relates to the place they occupy, to their respective size, to their projections and depressions, to the cavities whose parietes they form—every thing that relates to their internal structure, to the different proportions of their component parts, to the aggregation of some of these substances in certain points of their extent,—has been described by several modern anatomists with an accuracy which it would not be easy to surpass. Several, however, have not sufficiently appreciated the direct influence of their mode of union on the purposes which they are destined to fulfil; no one has insisted sufficiently on the manner in which they all concur to a principal object,—the preservation of the organs enclosed within the skull.

Hunauld, in a memoir inserted among those of the Academy of Sciences for the year 1730, was the first that endeavoured to account for the arrangement of the articulating surfaces of the bones of the skull. After laying down a few principles on the theory of arches, and after shewing, that the difference of extent of their concave and convex surfaces renders it necessary that the parts of which they are formed should be shaped obliquely, he explains the advantages of the squamous articulation between the temporal and parietal bones.

When the arch of the cranium is loaded with a very heavy burthen, the temporal bones prevent the parietals on which the effort is immediately applied from being forced inwardly, or from being separated outwardly. Hunauld very aptly compares them to buttresses, which are to the parietal bones of the same use as walls to the arches which they support.

Bordeu* endeavoured to apply to the bones of the face the principles by which Hunauld has been guided in his investigation with regard to those of the skull. According to Bordeu, the greater part of the bones of the upper jaw, but particularly the superior maxillary bones, resist the effort of the lower jaw, which, by acting on the upper dental arch, has a perpetual tendency to force upward, or to separate outwardly, the bones in which the teeth of that jaw are inserted. As the greatest stress of the effort determines them upward, it is likewise in that direction that the bones of the upper jaw rest most powerfully on those of the skull. The author concludes this very ingenious memoir, by proposing to physiologists the solution of the following problem: "When a man supports a great weight on his head, and holds at the same time any thing very firmly between his teeth, which is the bone of the head that is most acted upon? which supports the weight of the whole machine?"

The body of the sphenoid, and especially its posterior half, appears to me to be the central point on which the united efforts of the bones of the skull and of the face act, in the case supposed by Bordeu.

The sphenoid is connected with all the other bones of the skull; it is immediately connected with several of the bones of the face, as with the malar bones, with the palatine bones, with the vomer, and sometimes with the superior maxillary bones. These bones of the face, in the case in question, alone support the lower jaw against the upper. The ethmoid bone, the ossa unguis, and the inferior turbinated bones, are thin and frail, and serve merely to form the nasal fossæ, of which they increase the windings, and do not deserve to be attended to in this investigation. The vomer may, it is true, communicate to the ethmoid, in an inferior degree, a part of the effort; for the anterior part of its upper edge is articulated with the perpendicular lamellæ of

* *Académie des Sciences, Mémoires présentes par les Savans Etrangers*, tom. iii.

that bone; but this quantity is very small, as the vomer is thin, and transmits it almost wholly to the body of the sphenoid, with the lower face of which it is articulated.

The effort exerted on the bones of the upper jaw is transmitted, by means of the nasal processes of the upper maxillary bones, by the orbitar and zygomatic processes of the malar bones, and by the upper edge of the palate bones and of the vomer, to the frontal, to the temporal, and sphenoidal bones.

If we wish to determine what becomes of the greater part of the effort transmitted to the frontal bone by the maxillary and malar bones, we may observe, in the first place, that it is articulated with the sphenoid bone by the whole of its lower edge, which is bevelled at its inner part, so that it is covered by the alæ minores of the os sphenoides, which is shaped obliquely at the outer part of the bone. The frontal bone is articulated, besides, with the latter and inferior parts of its upper edge. The remainder of this upper part is united to the anterior edge of the parietal bones, which, by means of a slope in a different direction, rest on the middle part of this edge, while the frontal bone is applied to them laterally.

This bone, which the effort tends to force upward and backward, cannot yield to this double impulse; for, on the one hand, its mode of articulation with the anterior edge of the alæ minores of the sphenoidal bone, and the internal part of the anterior edge of the parietal bones, resist this tendency upward, while the resistance from the latter prevents them being forced backward. That share of the effort which affects the parietal bones follows the curved line described by these bones, and extends along that formed by the occipital, and thus reaches the posterior face of the body of the sphenoid bone.

The portion directly transmitted to the anterior and inferior face of this bone by the ossa palati and by the vomer, is inconsiderable, and proportioned to their thinness. The anterior half of the body of the sphenoid bone, hollowed by the sphenoidal sinus, would have been incapable of supporting greater pressure. Lastly, the situation of the body, placed between the dental arches, in front of the place occupied by the ossa palati, explains why this transmission is chiefly effected by the upper maxillary bones.

The above is the manner in which the effort exerted from below upward, by the lower on the upper jaw, is carried to the anterior, posterior, and inferior faces of the body of the sphenoid bone.

The temporal bones, which are affected by it in a very slight degree, by means of the zygomatic processes of the malar bones, support the greater weight of the effort acting from above downward, or from the arch of the skull towards its base. The weight laid on the head tends to depress or to separate the parietal bones, which resist the pressure, in consequence of the support afforded them by the temporals. These transmit the effort to the lateral and posterior parts of the body of the sphenoid, by means of the alæ majores of that bone, which are articulated, along the whole extent of their external edge, and along the posterior fourth of their internal edge, with the temporals. Besides, the upper extremity of the alæ majores is sloped on the inner part of the bone, that it may be articulated with the anterior and inferior angles of the parietal bones, and answer the same purpose to them as the squamous portion of the temporals.

The lateral and posterior parts of the body of the sphenoid support, therefore, almost the whole effort of the pressure applied to the parietal bones. It is communicated to them by the alæ majores, which receive it themselves, either directly at the anterior and inferior angles of this bone, or through the medium of the temporals. The small portion of the effort transmitted by the

latter to the occipital follows the curved line of this bone, and is felt on the posterior face of the body of the sphenoid.

To the effort resulting from the pressure exerted by the body on the summit of the head, one should add that occasioned by the contraction of the muscles which elevate the lower jaw. These tend to depress the temporal, the malar, and sphenoid bones ; and in this action they employ a power equal to that by which they raise the lower jaw, and press it firmly against the upper.

The effort exerted from the arch to the base of the skull depends, therefore, on two very different causes : the portion resulting from the action of the elevators of the lower jaw is equal to the effort exerted from below upward by this bone. After what has been stated, it would be useless to say any thing further of the manner in which the effort is transmitted : we may merely observe, that the least powerful of these muscles, the internal pterygoid, tends to draw the sphenoid downward, and prevents this bone, fixed like a wedge, with its base turned upward, from being disengaged by the effort applied to it by the bones between which it is situated.

The posterior, anterior, inferior, and lateral faces of the sphenoid bone support, therefore, the whole effort of the bones of the skull and face, on one another, when, the top of the head being loaded with a heavy burden, one presses at the same time something very firmly between the dental arches.

The anterior part of the body of the bone, containing the sphenoidal sinus, is thin and very frail ; the posterior part corresponding to the cella turcica, is alone capable of resisting the effort which I believe it is destined to sustain ;* hence it is at this point that ossification begins ; and this confirms the observation of Kerkringius, that the spot at which bones begin to ossify is that on which they have to bear the greatest effort ; thus the alæ majores, by means of which the greatest part of the efforts that the body of the sphenoid has to support, arise from the lateral parts of its posterior half, by an origin of considerable size, and which is further increased by the base of the pterygoid processes which arise from its lower part.

The shocks which the cranium has often to endure are chiefly experienced towards its base, where its parietes are thickest, and offer the greatest resistance. This transmission of the shock to the base explains wherefore, in wounds or injuries of the head, fractures often take place in the base, whilst the rest of the skull, even at the place of the external injury, preserved its integrity.

I have in this inquiry purposely avoided mentioning the support which the head receives from the vertebral column, and which, in the case under consideration, is of use merely in preventing it from yielding to the law of gravitation. If the bones of the skull and of the face had pressed, during the effort which they sustain, on the circumference of the foramen magnum, this aperture would have been incapable of increasing its dimensions, and this would have been attended with the most serious inconveniences.

The name given by the ancients to the bone whose principal use has just been explained, is composed of *sphenos*, which means a wedge, and *eidos*, which signifies resemblance ; and would lead one to think that they were not ignorant of its uses. From its situation, at the middle and inferior part of

* The sphenoidal sinus is prolonged, it is true, into this posterior part of the body of the bone, in persons far advanced in years ; but the parietes of this portion of its cavity are of considerable thickness. The anterior part of the basilary process of the occipital bone is then firmly united to the sphenoid, and may be considered as forming a part of that bone, from which it cannot be detached. The cranium of an old man, in this respect, resembles that of several quadrupeds, in which the union of the sphenoid to the occipital bone takes place so early, that these two bones might well be considered as forming but one.

the skull, and from its various connexions with the bones which form this osseous case, it is to them of the same use as the key-stone of arches, with regard to the different parts of which they are formed. The numerous connexions required for this purpose, account for its strange and irregular form, and for the different shapes of its articular surfaces, and the great number of its projections, which render the demonstration of this bone so complicated, and a knowledge of it so difficult.

It is more advantageous, with regard to the brain, that the skull should be formed of several bones, than if it had consisted of a single bone. It resists more effectually the blows it receives, their effect being lessened in passing from one bone to the other, and being interrupted in the obscure motions which they may experience at their sutures; its rounded form increases likewise its power of resistance. This force would be equal, in every point of the parietes of the cranium, if the form of that cavity were completely spherical, and if the thickness of its parietes were, in every part of it, the same. In that case, no fractures by *contre coup* could occur,—a kind of lesion occasioned by the unequal resistance of the bones of the head to the force applied to their surface. The pericranium, the hairy scalp, the muscles which cover it, and the great quantity of hair on its surface, serve, besides, to defend the brain, and are well calculated to break the force of blows applied to the cranium.

In addition to this hard and unyielding case, there lies over the brain a treble membranous covering, formed by the dura mater, which owes its name to the erroneous opinion, according to which it was supposed to form all the other membranes of the body; it is further covered by the tunica arachnoidea, so called from the extreme minuteness of its tissue; and by the pia mater, which adheres firmly to the substance of the brain.

The dura mater lines not only the inside of the skull and of the vertebral canal, which may be considered as a prolongation of it, but likewise penetrates between the different parts of the cerebral mass, supports them in the different positions of the head, and prevents mutual compression. Thus, the greatest of its folds, the falx, stretched between the crysta galli of the ethmoid bone, and the inner protuberance of the occipital bone, prevents the two hemispheres of the brain, between which it lies, from compressing each other, when the body is on the side, and maintains on the other hand the tentorium cerebelli in the state of tension necessary to enable it to support the weight of the posterior lobes of the brain. This second fold of the dura mater is of a semicircular form, and separates the portion of the skull which contains the brain from that in which the cerebellum is situated. It is kept in a state of tension by the falx cerebri, on which it also exerts the same action: it does not present an horizontal plane to the portion of brain which lies upon it, but one that slopes in every direction towards the parietes of the skull, to which it transmits most of the weight which it has to support. The tentorium cerebelli, which thus divides the internal cavity of the skull into two parts of unequal dimensions, is bony in some animals that move by bounding and with rapid action: this is the case with the cat, which can, without being stunned, take leaps from a considerable height. By means of this complete partition, the two portions of the brain are prevented from pressing on each other, in the violent concussions which they experience.

The tunica arachnoides, according to Bohn,* who was thoroughly acquainted with its structure, and who has given a very beautiful plate of it, is the secretory organ of the serum which moistens the internal surface

* *Dissertatio de Continuationibus Membranarum.* Lugdun. Bat. 4to, 1763.

of the dura mater, a fibrous membrane which serves as a periosteum to the bones it lines.*

CXLIII. *Of the size of the brain.*† —Of all animals, man has the most capacious skull in proportion to his face; and as the bulk of the brain is always of a size proportioned to that of the osseous case which contains it, the brain is also most bulky in man. This difference of size between the cranium and face may be taken as the measure of the human understanding and of the instinct of the lower animals: the stupidity and ferocity of the latter are greater according as the proportions of these two parts of their skull vary from those of the human head.

To express this difference of size, Camper imagined a vertical line, drawn from the forehead to the chin, and perpendicular to another drawn in the direction of the base of the skull. He has called the first of these lines *facial*, the second *palatine* or *mental.* It is easy to understand, that as the projection of the forehead is determined by the size of the skull, the larger it is the more the angle at which the facial line meets that from the base of the skull must be obtuse. In a well-formed European head, the facial line meets the palatine at an angle nearly straight (of between 80 and 90 degrees). When the angle is quite straight, and the line which measures the height of the face is completely vertical, the head is of the most beautiful form possible; it approaches most to that conventional degree of perfection which is termed ideal beauty. If the facial line slopes backward, it forms with the palatine line an angle more or less acute; and projecting forward, the inclination increases, and the sinus of the angle is shorter. If from man we pass to monkeys, then to quadrupeds, to birds, reptiles, and fishes, we find this line slope more and more, and at last become almost parallel to the mental, as in reptiles, and in fishes with flat heads. If, on the contrary, we ascend from man to the gods, whose images have been transmitted to us by the ancients, we find the facial line to incline in a different direction: the angle then enlarges and becomes more or less obtuse. From this inclination forward of the facial line there results an air of grandeur and majesty, a projecting forehead, indicating a voluminous brain and a divine intellect.

To obtain with precision, by this means, the respective dimensions of the skull and face, one must measure, not only the outside, but likewise draw the tangents on the internal surfaces, after dividing the head vertically. There are, in fact, animals in which the sinuses of the frontal bone are so large that a considerable portion of the parietes of the skull is protruded by their cells. Thus, in the dog, in the elephant, in the owl, &c. the apparent size of the skull exceeds greatly its real capacity.‡

The relative size of the head, and consequently the proportionate bulk of the brain, is inconsiderable in very tall and muscular subjects: this fact will be confirmed by observing the proportions of antique statues. In all those which represent heroes or athletes gifted with a prodigious bodily power, the head is very small in proportion to the rest of the body. In the statues of Hercules, the head scarcely equals in size the top of the shoulder. The statues alone of the king of the gods present the singular combination of an enormous head resting on limbs of a proportionate size: but the Greek

* Analogous to the serous membranes which line the cavities of the body, the arachnoid is a shut sac, whose internal surface is every where in contact with itself, while its external surface adheres to the two other meninges. The serosity which exudes from the internal surface of the arachnoid differs from that which escapes from the other serous membranes, owing to the almost entire absence of albumen from the former. The exhalation that takes place from this membrane appears to be the source of a more limpid and dilute effusion, even in disease, than that which is observed in the other serous cavities.—*J. C.*

† See APPENDIX, Note G G.

‡ See APPENDIX, Notes G G.

artists have transgressed the laws of nature only in favour of the god that rules over her, as if a vast brain had been necessary to one whose intellect carries him, at a glance, over the whole universe. The relatively small dimensions of the head in athletes depend on this circumstance, that in such men the excessive development of the organs of motion gives to the body, and especially to the limbs, an enormous size; while the head, covered by few muscles, remains very small. Soëmmering has stated, that the head in women is larger than in men, and that their brain is heavier; but it must be recollected, that this great anatomist obtained this result by examining two bodies, male and female, of the same length. Now, the absolute size being the same, the proportionate magnitude was not so, and he was wrong in comparing the head, the skull, and brain of a very tall woman to that of a very short man.

It has long been believed that there exists a connexion between the bulk of the cerebral mass and the energy of the intellectual faculties. It has been thought that, in general, men whose mind is most capacious, whose genius is most capable of bold conceptions, had a large head supported on a short neck. The exceptions to this general rule have been so numerous, that many have doubted its truth: should it then be absolutely rejected? and will it be allowed to be wholly without foundation, when we consider that man, the only rational being out of so great a number, and some of which bear to him a considerable resemblance both as to organisation and structure, is likewise the only animal in which the brain, properly so called, is largest in proportion to the cerebellum, to the spinal marrow, to the nerves, and to the other parts of the body? Why may it not be with the brain as with the other organs, which fulfil their functions the better from being more completely developed? It should be recollected, in this comparison of the brain and of the intellectual powers, that several causes may give to this viscus an unnatural degree of enlargement. Thus, in subjects of a leucophlegmatic temperament, the tardy ossification of the bones of the skull causes the brain, gorged with aqueous fluids, to acquire a considerable size, without its containing a greater quantity of real medullary substance. Hence it is observed, that men of this temperament are most frequently unfit for mental exertion, and rarely succeed in undertakings that require activity and perseverance.*

CXLIV. *Structure of the cerebral mass.*—What we know of the brain serves only to shew us that we are ignorant of much more. All that we know of it consists of tolerably exact notions of its external conformation, its colour, its density, and of the different substances that enter into its composition; but the knowledge of its intimate structure is yet a mystery, which will not be so soon unveiled to us. The brain, properly called, is divided by a longitudinal furrow into two lobes of equal bulk. Gunzius, however, imagined that he found the right lobe, or hemisphere, a little larger than the left: but even were this fact as certain as it is doubtful, we could not thereby explain the predominant force of the right side of the body; since the nerves which are distributed to this side rise from the left lobe of the brain, in the substance of which all the roots of these cords cross. This fact of the crossing of the nerves at their origin is proved by a multitude of pathological observations, in which the injury of a lobe is always found to bring on paralysis, convulsion, or some other symptomatic affection, on the opposite side of the body,—unless you choose to explain this phenomenon by admitting a necessary equilibrium in the action of the two lobes—an equilibrium, the dis-

* See, in the article on Temperaments, an account of the influence of the physical organisation on the moral disposition and on the intellectual faculties.

turbance of which is the occasion that the sound lobe, acting with more force, compresses the origin of the nerves on its side, and determines paralysis. May not the want of judgment, the unevenness of humour and character, depend on the want of harmony between the two corresponding halves of the cerebral mass?

In order to disclose, better than had before been done, the structure of the brain, M. Gall began his dissection at the lower part: examining, in the first place, the anterior part of the prolongation, known under the name of cauda of the medulla oblongata, he finds the two pyramidical eminences. If you part the two edges of the median line below the furrow which separates the two pyramids, you see distinctly the crossing of three or four cords, or fasciculi of nerves, which, consisting of many filaments, tend obliquely from right to left, and *vice versâ*. This crossing of nervous fibres, which is not found in any other part of the brain, had been observed by several anatomists: it is not known how it came to be forgotten; so that the most exact and latest among them, Boyer for instance, says that the crossing of the nerves cannot be proved by anatomy. These nervous cords, traced upwards, enlarge, strengthen, and, forming pyramidical eminences, ascend towards the tuber annulare. Having reached the ganglion, the fibres strike into it, and are lost in a mass of pulpy or grayish substance, of the same nature as that which, under the name of cortical substance, covers the two lobes of the brain. This grayish pulp, distributed in various parts, may be considered, agreeably to the views of M. Gall, who calls it the matrix of the nerves, as the source from which the medullary fibres take their origin. These ascending fibres cross other transverse fibres, which, on either side, proceed from the crura of the cerebellum, enlarged and multiplied by means of their passage through the gray substance which is found in the tuber annulare: they rise from it at its upper part in two fasciculi, which compose nearly the whole of the crura cerebri. The interior of these crura contains a certain quantity of gray substance, which is what nourishes the nervous fibre. On reaching the ventricles, these peduncles, or rather the two fasciculi of fibres which form them, meet with large ganglions, full of gray substance: they have long been called thalami optici, though they do not give origin to the optic nerves. There the fibres are sensibly enlarged, and they pass from the thalami optici into new ganglions. These are the corpora striata; and the striæ which are apparent on cutting these pyriform masses of gray substance are only the same fibres, which, enlarged, multiplied, and radiated, spread out in the manner of a fan towards the lobes of the brain, where, after forming by their expansion a whitish and fibrous substance, they terminate at the outer part of that viscus, forming its convolutions, all covered with the substance in which are terminated in like manner the extremities of the diverging fibres. From this gray substance proceed converging fibres, tending from all parts of the periphery to the centre of the brain, where they unite to form the different commissures, the corpus callosum, and other productions destined to facilitate the communication of the two hemispheres.*

The exterior of the brain may, therefore, be considered as a vast nervous membrane, formed by the gray substance. To have a due conception of its extent, it must be understood that the convolutions of the brain are a sort of duplicatures, susceptible of extension by the unfolding of two contiguous medullary laminæ which form its base. The exterior surface of the brain, by means of this unfolding, offers then some relation to the skin,—a vast nervous expanse every where covered by a sort of pulpy substance, known by the name of the rete mucosum of Malpighi. M. Gall compares this cutaneous

* See APPENDIX, Notes G G.

pulp to the cineritious substance which forms the outer part of the brain; and, I must confess, it is not every one that will admit the analogy. However, true it is that the brain consists principally of a mass of ganglions,—that it produces neither the elongated medulla nor the spinal marrow,—that this last may be considered as a series of ganglions united together,—that the vertebral nerves arise from the grayish pulp of which the spinal marrow is full, as is best seen in animals without a brain, but not the less provided with a spinal marrow, or series of ganglions, from which the nerves arise,—and that the ganglions, or rather the gray substance which they always shew, produce the nervous fibres, and thicken the nervous cords that pass through them.

That is the only use that can be assigned to these parts of the nervous system; for if they were meant to withdraw from the dominion of the will the parts in which they are found, why do not the ganglions of the vertebral nerves fulfil the same function? All these nerves communicate by reciprocal anastomoses. These communications in man are equivalent to a real continuity. In truth, the brain acts upon the nerves that proceed from the spinal marrow as if this were one of its productions, and all the nervous fibres spread through the different organs had an extremity terminating in this viscus.

One thing well worthy of attention, and on which no anatomist has dwelt, is, that the brain of the fœtus, and of the child just born, appears to consist almost entirely of a cineritious pulp, to such a degree that the medullary substance is with difficulty perceived in it. Would it be absurd to believe, that the medullary part of the brain does not take its perfect organisation till after birth, by the development of the fasciculi of medullary fibres in the midst of these masses of cineritious substance, which must be considered as the common source from which the nerves have their origin; or, to use the language of Gall, as the uterus which gives them birth. The almost total inactivity, the passive state of the brain in the fœtus, makes unnecessary there the existence of the medullary apparatus, to which the most important operations of intelligence seem intrusted. Its first rudiments are found in the fœtus at its full time. That fibro-medullary apparatus will be strengthened by the exercise of thought, as the muscles are seen to enlarge and perfect their growth by the effect of muscular action.*

CXLV. *Circulation in the brain.*—I have said that the blood, in its circular course, does not traverse the different parts of the body with uniform velocity,—that there are partial circulations in the midst of the general circulation. In no organ are the laws to which this function is subjected more remarkably modified than in the brain. There is none which receives, in proportion to its bulk, larger arteries and more in number. The internal carotid and vertebral arteries, as we may satisfy ourselves from the calculations of Haller, carry thither a great portion of the whole quantity of blood that flows along the aorta (from a third to a half).

The blood which goes to the brain, said Boerhaave, is more aerated than that which is distributed to the other parts: the observation is not without foundation. Though the blood which the contractions of the left ventricle

* See the APPENDIX, Notes G G, where the reader will find some observations by the Editor, on the development of the spinal cord and brain, and on the functions of the cerebro-spinal nervous system in man and the lower animals. The views contained in that part of our Appendix were published in the former edition of our Notes, before the publication of the work of M. Serres, which soon afterwards appeared, and fully confirmed them. We think it right thus to allude to the circumstance, as some physiological writers have taken occasion to quote M. Serres as the originator of these views, without reference to the earlier publication of similar opinions in this country,—opinions which had been long entertained, and frequently discussed by us with anatomists and physiologists, both in this country and on the continent, before their publication.—*J. C.*

send into the vessels arising from the arch of the aorta does not undergo at the place of this curvature a mechanical separation, carrying its lighter parts towards the head; it is not less true that this blood, just passing from the contact of the air in the lungs, possesses, in the highest degree, all the peculiar qualities of arterial blood. So great a quantity of light, red, frothy blood, impregnated with caloric and oxygen, coming upon the brain with all the force it has received from the action of the heart, would unavoidably have deranged its soft and delicate structure, if Nature had not multiplied precautions to weaken its impulse.

The fluid, compelled to ascend against its own weight, loses, from that cause alone, a part of its motion. The vertical column must strike against the angular curvature which the internal carotid makes in its passage along the osseous canal of the petrous portion of the temporal bone; and as this curvature, supported by hard parts, cannot straighten itself, the column of blood is violently broken, and turned out of its first direction with considerable loss of velocity.

The artery immersed in the blood of the cavernous sinus, as it comes out from the carotid canal, is very easily dilated. Finally, the branches into which it parts on reaching the base of the brain have coats exceedingly thin, and so weak that they collapse when they are empty like those of the veins. This weakness of the cerebral arteries explains their frequent ruptures, when the heart sends the blood into them too violently; and it is thus that the greater part of sanguineous apoplexies are occasioned, many of which, however, take effect without rupture, and by the mere transudation of blood through the coats of the arteries. These vessels, like the branches arising from their divisions, are lodged in the depressions with which the base of the brain is furrowed, and do not enter its substance till they are reduced to a state of extreme tenuity, by the further divisions they undergo in the tissue of the pia mater.

Notwithstanding the proximity of the brain to the heart, the blood reaches it, then, with an exceedingly slackened motion; it returns, on the contrary, with a motion progressively accelerated. The position of the veins at the upper part of the brain, between its convex surface and the hollow of the skull, causes these vessels, gently compressed by the alternate motions of rising and falling of the cerebral mass, to disgorge their contents readily into the membranous reservoirs of the dura mater, known by the name of sinuses. These, all communicating together, offer to this fluid a sufficiently large receptacle, from which it passes into the great jugular vein, which is to carry it again into the general course of the circulation. Not only is the calibre of this vein considerable, but its coats too, of little thickness, are very extensible: so much so, that it acquires by injection a calibre superior to that of the venæ cavæ. The flowing of the blood is favoured by its own weight, which makes a retrograde course very difficult.* Thus, to sum up all that is peculiar in the cerebral circulation, the brain receives in great quantity a blood abounding in oxygen; the fluid finds in its course thither many obstacles which impede and slacken its impulse, whilst all, on the contrary, favour its return, and prevent venous congestion.† Let me observe, to conclude what I have to say on the circulation of the brain, that that of the eye is nearly allied to it, since the ophthalmic artery is given out by the internal carotid, and the ophthalmic

* In preventing this reflux, there is no use of valves, which the jugular vein is entirely without. It is sufficiently prevented by the direction in which the blood flows, and the extensibility of its coats. This great size which the vein can acquire would have made useless the valvular folds, and insufficient to stop the canal, in that great augmentation of its dimensions.

† The transverse anastomoses of the arteries at the base of the brain are very proper for distributing the blood in equal quantity to all parts of this viscus.

vein empties itself into the cavernous sinus of the dura mater. Accordingly, the redness of the conjunctiva, the prominence, the brightness, the moistness of the eyes, indicate a stronger determination of the blood towards the brain. Thus, the eyes are animated at the approach of apoplexy, in the transport of a burning fever, and during delirium, which is a dangerous symptom of malignant or ataxic fevers. On this connexion of the vessels of the eye and brain depends the lividity of the conjunctiva, whose veins, injected with a dark-coloured blood, indicate the fulness of the brain in the generality of cases of suffocation.

CXLVI. *Of the connexion between the action of the brain and that of the heart.*—It is possible, as was done by Galen, to tie both carotids in a living animal without its appearing sensibly affected by it; but if, as has never yet been done, both the vertebral arteries are tied, the animal drops instantly, and dies at the end of a few seconds. To perform this experiment, it is necessary, after tying the carotid arteries of a dog, to remove the soft parts which cover the side of the neck; then with needles, bent in a semicircular form, passed into the flesh along the sides of the articulation of the cervical vertebræ, to apply ligatures to the arteries which ascend along their transverse processes. The same effect, viz. the speedy death of the animal, is produced by tying the ascending aorta in an herbivorous quadruped.

These experiments, which have been repeated a number of times, decidedly prove the necessity of the action of the heart on the brain in preserving life. But how does this action operate? Is it merely mechanical? Does it consist solely in the gentle pressure which the arteries of the brain exert on the substance of this viscus, or is it merely to the intercepted arterial blood which the contractions of the heart determine towards the brain, that death is to be attributed? The latter opinion seems to me the most probable; for if, the moment the vertebrals have been tied, the carotids are laid open, and the pipe of a syringe adapted to them, and any fluid whatever is then injected with a moderate degree of force, and at nearly the same intervals as those of the circulation, the animal will not be restored to life.

The heart and brain are, therefore, united to each other by the strictest connexion; the continual access of the blood flowing along the arteries of the head is, indeed, absolutely necessary to the preservation of life; if intercepted for one moment, the animal is infallibly destroyed.

The energy of the brain appears, in general, to bear a relation to the quantity of arterial blood which it receives. I know a literary man who, in the ardour of composition, exhibits all the symptoms of a kind of brain fever. His face becomes red and animated, his eyes sparkling; the carotids pulsate violently; the jugular veins are swollen; every thing indicates that the blood is carried to the brain with an impetus, and in a quantity, proportioned to its degree of excitement. It is, indeed, only during this kind of erection of the cerebral organ, that his ideas flow without effort, and that his fruitful imagination traces, at pleasure, the most beautiful descriptions. Nothing is so favourable to this condition as remaining long in a recumbent posture: in this horizontal posture, the determination of the fluids towards the head is the more easy, as the limbs, which are perfectly quiescent, do not divert its course. He can bring on this state by fixing his attention steadfastly on one object. May not the brain, which is the seat of this intellectual action, be considered as a centre of fluxion; and may not the stimulus of the mind be compared, as to its effects, to any other stimulus, chemical or mechanical?

A young man of a sanguineous temperament, subject to inflammatory fevers, which always terminate by a profuse bleeding at the nose, experiences, during the febrile paroxysms, a remarkable increase of his intellectual powers,

and of the activity of his imagination. Authors had already observed, that in certain febrile affections patients of very ordinary powers of mind would sometimes rise to ideas which in a state of health would have exceeded the limits of their conception. May we not adduce these facts in opposition to the theory of a celebrated physician, who considers a diminution of the energy of the brain to be the essential character of fever?

It is well known that the difference of the length of the neck, and, consequently, the greater or lesser degree of vicinity of the heart and brain, give a tolerably just measure of the intellect of man, and of the instinct of the lower animals; the disproportionaté length of the neck has ever been considered as the emblem of stupidity.

In the actual state of our knowledge, is it possible to determine in what manner arterial blood acts on the brain? Are oxygen or caloric, of which it is the vehicle, separated from it by this viscus, so as to become the principle of sensation and emotion? or do they merely preserve it in the degree of consistence necessary to the exercise of its functions? What is to be thought of the opinion of those chemists who consider the brain as a mere albuminous mass, concreted by oxygen, and of a consistence varying in different persons, according to the age, the sex, or the state of health or disease? Any answer that one might give to these premature questions would be but a simple conjecture, to which it would be difficult to assign any degree of probability.*

CXLVII. *Of the theory of syncope.*—If we consider the action of the heart on the brain, we are naturally led to admit its necessity to the maintenance of life, and to deduce from its momentary suspension the theory of syncope. Several authors have attempted to explain the manner in which their proximate cause operates; but as not one of them has gone upon facts ascertained by experience, their explanations do not all agree with what is learnt from observing the phenomena of these diseases.

To satisfy oneself that the momentary cessation of the action of the heart and the brain is the immediate cause of syncope, one need but read with attention the chapter which Cullen, in his work on the practice of physic, has devoted to the consideration of this kind of affection. It will be readily understood, that their occasional causes, the varieties of which determine their different kinds, exist in the heart or great blood-vessels, or act on the epigastric centre, and affect the brain only in a secondary manner. Thus, the

* The connexion which exists between the functions of the heart and those of the brain are not only manifest in their healthy relations, but also in their disordered actions. Portal, Bricheteau, and Testa, had pointed out this connexion in the diseases of these organs; and, more recently, Dr. Craigie has contended for its importance, although some contemporary pathologists have denied its existence. This pathologist, after stating his experience on the subject, draws the following inferences from it:—

"1st. It is quite obvious that several maladies of the heart, such as ossification of the left side, or of the artery connected with it; ossification of the neutral valve; of the semi-lunar valves; aretation of the apertures, either auriculo-ventricular or aortic;—have a tendency to terminate in extravasation within the cranium, producing apoplexy, paralysis, or a comatose state terminating in death.

"2d, It is by no means difficult to see how these effects in the cerebral organ result from an irregular and disordered action of the heart. The difficulty which the blood experiences in passing either, 1st, through the auriculo-ventricular opening; 2d, the aortic orifice; 3d, along the aorta,—necessarily produces a stagnation and congestion, 1st, in the pulmonary veins; 2d, in the pulmonary artery; 3d, in the right side of the heart. The effect of this is to retard or impede very remarkably the return of the blood from the cerebral veins, and consecutively either to distend them, to rupture them, or to occasion an effusion of the serous part of the blood, as we find in other examples of obstructed venous circulation."—(*Edin. Med. Jour.* No. 74.)—Dr. Craigie has, however, omitted to mention the influence of active enlargement of the left side of the heart in producing apoplexy, owing to the increased impulse or determination of blood which is thus produced, and to which the brain is most obnoxious. This, and every other form of connexion of disease of the heart with apoplexy, can only be viewed as occasional occurrences; the former states being by no means necessarily followed by the latter. —*J. C.*

kinds of syncope occasioned by aneurismal dilatations of the heart and great vessels, by polypous concretions formed in these passages, by ossification of their parietes or of their valves, evidently depend on the extreme debility, or on the entire cessation of the action of the heart and arteries. Their parietes, ossified, dilated, adhering to the neighbouring parts, or compressed by any fluid whatever, no longer act on the blood with sufficient force ; or else this fluid is interrupted in its progress by some obstacle within its canal, as a polypous concretion, an ossified and immovable valve. Cullen very justly termed these, idiopathic or cardiac syncopes.

To the above may be added plethoric syncope, depending on a congestion of blood in the cavities of the heart : the contractions of this organ become more frequent, it struggles to part with this excess of blood, which is injurious to the performance of its functions; but to this unusual excitement, by which the contractility of its fibres is exhausted, there succeeds a kind of paralysis, necessarily accompanied by syncope.

One may, likewise, include the fainting attending copious blood-letting : the rapid detraction of a certain quantity of the vivifying principle deprives the heart of the stimulus necessary to keep up its action. The same effect is produced by drawing off the water contained in the abdomen in ascites : a considerable number of vessels cease to be compressed ; the blood which they before refused to transmit is sent to them in profusion ; the quantity sent to the brain by the heart is lessened in the same proportion, and becomes insufficient for its excitement. Among the syncopes called idiopathic, one may enumerate those occuring in the last stage of the scurvy, the principal character of which is an excessive debility of the muscles employed in the vital functions and in voluntary motion. Lastly, we may add asphyxia from strangulation, from drowning, and from the gases unfit for respiration ; affections in which the blood being deprived of the principle which enables it to determine the contractions of the heart, the circulation becomes interrupted. If the blood loses, by slow degrees, its stimulating qualities, the action of the heart, gradually weakened, impels towards the brain a blood which, by its qualities, partakes of the nature of venous blood, and which, like it, cannot preserve the natural economy of the brain. It was thought, that by injecting a few bubbles of air into the jugular vein of a dog, one might occasion in the animal immediate syncope, and that it was even sufficient to deprive it of life ; but the late experiments of M. Nysten have proved, that the atmospherical air produces these bad effects only when injected in a quantity sufficient to distend in excess the cavities of the heart, or when, by being injected into the arteries, it compresses the brain. When injected only in a small quantity, the gas dissolved in the venous blood is conveyed along with it to the lungs, and is thence exhaled in respiration.

A second class of occasional causes consists of those which, by acting on the epigastric centre, determine by sympathy a cessation of the pulsations of the heart, and the syncope necessarily attending this cessation. Such are the violent emotions of the soul,—terror, an excess of joy, an irresistible aversion to certain kinds of food, the dread which is felt on the unexpected sight of an object, the disagreeable impression occasioned by certain odours, &c. In all these cases, there is felt in the region of the diaphragm an inward sensation of a certain degree of emotion. From the solar plexus of the great sympathetic nerve, which, according to the general opinion, is considered as the seat of this sensation, its effects extend to the other abdominal and thoracic plexuses. The heart, the greater part of whose nerves arise from the great sympathetic, is particularly affected by this sensation. Its action is at times merely disturbed by it, and at others wholly suspended. The pulse be-

comes insensible, the countenance pale, the extremities cold, and syncope ensues. This is the course of things when a narcotic or poisonous substance has been taken into the stomach; when this viscus is much debilitated in consequence of long fasting, or when it contains indigestible substances; in cholic, and in hysterical affections.

This last class of occasional causes does not act directly, and produces syncope only at a distant period; but the result is always the same. It happens in all these cases, that as the arteries of the head no longer receive as much blood as in health, the brain falls into a kind of collapse, which occasions a momentary cessation of the intellectual faculties, of the vital functions, and of voluntary motion.

Morgagni, in treating of diseases according to their anatomical order, ranks lypothymia among the affections of the chest, because the viscera contained in that cavity shew marks of organic affection in persons who, during life, were subject to frequent fainting.

The compression of the brain, by a fluid effused on the dura mater, in wounds of the head, does not produce real syncope, but rather a state of stupor. All causes acting in this manner on the brain produce comatose, and even apoplectic affections. When a man, on being exasperated, falls into a violent and sudden fit of passion, his face becomes flushed, and he is affected with vertigo and fainting. There is no loss of colour, no loss of pulse; the latter, on the contrary, generally beats with more force. This is not syncope, but the first stage of apoplexy, occasioned by the mechanical pressure on the brain, towards which the blood is carried suddenly and in too great a quantity.

I might support this theory of syncope by additional proofs drawn from the circumstances which favour the action of the causes giving rise to affections of this kind. For instance, syncope comes on almost always when we are in either an erect or sitting attitude, and in such a case it is right to lay the patient in an horizontal posture. Patients debilitated by long diseases faint the moment they attempt to rise, and recover on returning to the recumbent posture. Now, how are we to explain this effect of standing, in persons in whom the mass of humours is much impoverished, and whose organic action is extremely languid, unless by the greater difficulty to the return of the blood from the more depending parts, and on the difficulty in ascending of that which the contractions of the heart send towards the head? The phenomena of the circulation are, under such circumstances, more subject to the laws of hydraulics than when the body is in a state of health; the living solid yields more easily to the laws of physics and mechanics; and, according to the sublime idea of the father of physic, our individual nature approaches more nearly to universal nature.

CXLVIII. *Of the motions of the brain.*—Are the alternate motions of elevation and depression seen, when the brain is exposed, exclusively isochronous to the pulsations of the heart and arteries, or do they correspond at the same time to those of respiration? Such is the physiological problem of which I am about to attempt the solution.

Those authors who admit the existence of motions in the dura mater do not agree as to the cause which produces them. Some, and among others, Willis and Baglivi, thought they had discovered muscular fibres, and ascribed these motions to their action: others, as Fallopius and Bauhinus, attributed these motions to the pulsations of the arteries of that membrane. The dura mater possesses no contractile power; its firm adhesion to the inside of the skull would, besides, prevent any such motion. The motion observed in this membrane is not occasioned by the action of its vessels; for, as Lorry

observes, the arteries of the stomach, of the intestines, and of the bladder, do not communicate any motion to the parietes of these hollow viscera, and yet, in number and size, they at least equal the meningeal arteries.

The motion observed in the dura mater is communicated to it by the cerebral mass which this membrane covers ; and this opinion of Galen, adopted by the greater number of anatomists, has been placed beyond a doubt by the experiments of Schlitting, of Lamure, Haller, and Vicq-d' Azyr. They have all observed, that on removing the dura mater, the brain continued to rise and fall ; and, with the exception of Schlitting, they agreed that the brain, absolutely passive, received from its vessel the motions in which the dura mater partook ; but are these motions communicated by the arteries or by the cerebral veins, and by the sinuses in which these terminate ? or, in other words, are they isochronous to the beats of the pulse, or to the contraction and successive dilatation of the chest, during respiration ?

Galen, in his treatise on this function, says, that the air admitted into the pulmonary organ distends the diaphragm, and is conveyed along the vertebral canal into the skull. According to this writer, the brain rises during the enlargement of the chest, and it sinks, on the contrary, when the parietes of this cavity are brought nearer to its axis. Schlitting, in a memoir presented to the Academy of Sciences, towards the middle of the last century, maintains that these motions take place in a different order, the elevation of the brain corresponding to expiration, and its depression to inspiration. Conceiving that he has determined this fact by a sufficient number of experiments, he does not enter into any explanation, and concludes his inquiry by asking whether the motions of the brain are occasioned by the afflux of air or of blood towards that organ.

Haller and Lamure attempted to answer this difficulty. They both performed a number of experiments on living animals, acknowledged the fact observed by Schlitting, and explained it in the following manner : as well as this last anatomist, Lamure believed that there is a vacuum between the dura and pia mater, by means of which the motions of the brain might always be performed. The existence of such a vacuum is disproved by the close contact of the membranes between which it is supposed to exist.

During expiration, continues Lamure, the parietes of the chest close on themselves, and lessen the extent of this cavity. The lungs, pressed in every direction, collapse ; the curvature of their vessels increases, and the blood flows along them with difficulty. The heart and great vessels thus compressed, the blood carried by the upper vena cava to the right auricle cannot be freely poured into this cavity, which empties itself with difficulty into the right ventricle, whose blood is unable to penetrate through the pulmonary tissue. On the other hand, as the lungs compress the vena cava, a regurgitation takes place of the blood which it was conveying to the heart ; forced back along the jugulars and vertebrals, it distends these vessels, the sinus of the dura mater which empty themselves into them, and the veins of the brain which terminate into these sinuses. Their distension accounts for the elevation of the cerebral mass,—an elevation soon followed by depression, when, on inspiration succeeding expiration and on the lungs dilating, the blood which fills the right cavities of the heart can freely penetrate into the pulmonary substance, and make way for that which the vena cava is bringing from the superior parts of the body.

Haller considered this reflux as very difficult, the blood having to rise against its own gravity ; and he admitted Lamure's explanations only in the forcible acts of respiration, as in coughing, laughing, and sneezing. He maintained that, in a state of health, there is to be observed during expiration,

a mere stagnation of the blood in the vessels which bring it from the internal parts of the skull. He further admits, on the testimony of a great number of authors, another order of motions depending on the pulsations of its arteries; so that, according to Haller, the cerebral mass is incessantly affected by motions, some of which depend on respiration, while the others are quite independent of it.

Lastly, according to Vicq-d'Azyr, the brain, on being exposed, presents a double motion, or rather two kinds of motion, from without; the one from the arteries, and which is least remarkable,—the other from the alternate motions of respiration.

CXLIX. This opposition between authors of reputation, and whose theories have in general been adopted, induced me to repeat the experiments which each of them brings in support of his own opinion, and to perform further experiments on this subject. My investigation soon convinced me, that these authors had given a statement of their opinions, and not of the fact itself. Indeed, the alternate motions of elevation and depression observed in the brain, are isochronous to the systole and diastole of the arteries at its base. The elevation of the brain corresponds to the dilatation of these vessels, its depression to their contractions. The process of respiration has nothing to do with this phenomenon; and even admitting the stagnation of the regurgitation of the blood in the jugular veins, the arrangement of the veins within the skull is such, that this stagnation or reflux could not produce alternate motions of the cerebral mass.

The brain receives its arteries from the carotids and vertebrals, after they have entered the skull, the former along the carotid canals, the latter through the foramen magnum of the occipital bone. It would be useless to describe their numerous divisions, their frequent anastomoses, the arterial circle, or rather polygon, formed by these anastomoses, and by means of which the carotid and vertebral arteries communicate together, by the side of the sella turcica. Haller has given a very correct view, and an excellent description of this part.* The account of the internal carotid artery published by that great anatomist is, according to Vicq-d'Azyr, a chef-d'œuvre of learning and precision; the same encomium might be bestowed on the latter, who gave a superb drawing of the same part. I shall content myself with observing, that the principal arterial trunks going to the brain are situated at the base of this viscus; that the branches into which these trunks divide, and the subdivisions of these branches, are likewise lodged at its base in a number of depressions; and that, in the last place, the arteries of the brain do not penetrate into its substance till after they have undergone in the tissue of the pia mater, which appears completely vascular, very minute subdivisions.

The vessels which return the portion of blood which has not been employed in the nutrition and growth of the brain, are, on the contrary, situated towards its upper part, between its convex surface and the arch of the cranium: each convolution contains a great vein which opens into the superior longitudinal sinus. The vena Galeni, which deposits into the sinus the blood brought from the choroid plexus; small veins which open into the cavernous sinuses; others, likewise very minute, which, passing through the foramina in the alæ majores of the sphenoid bone, contribute to form the venous plexus of the zygomatic fossa,—are the only exceptions to this general rule.

This being laid down on the arrangement of the arteries and veins, let us examine what will be the effect of their action with regard to this viscus.

The contractions of the heart propel the blood into the arterial tubes, which experience, especially at the place of their curvatures, a manifest displace-

* Fasciculi anatomici, f. vii. tab. ii.

ment at the time of their dilatation. All the arteries situated at the base of the brain experience both these effects at once. Their united efforts communicate to it a motion of elevation succeeded by depression, when, by their contraction, they re-act on the blood which fills them.

These motions take place only as long as the skull remains entire; this cavity is too accurately filled, and there is no void space between the membranes of the brain. Lorry, who, with good reason, denied the existence of such a space, committed an equally serious anatomical mistake in asserting, that as no motion could take place, on account of the state of fulness of the skull, it was effected in the ventricles, which he considers as real cavities; but which, as Haller has shewn, are, when in a natural state, merely surfaces in contact. No motion actually takes place, except in those cases in which there is a loss of substance in the parietes of the skull.

It is easy to conceive, however, that the brain, which is soft and of weak consistence, yields to the gentle pressure of its arterial vessels. Does not this continued action of the heart on the brain explain, in a satisfactory manner, the remarkable sympathy between those two organs, linked by such close connexions? It is, besides, of very manifest utility, and connected with the return of the blood distributed to the cerebral mass and to its envelopes. The veins which bring it back, alternately compressed against the arch of the skull, empty themselves more easily into the sinuses of the dura mater, towards which their course is retrograde, and unfavourable to the circulation of the blood which they pour into them.

When any thing impedes the free passage of the blood through the lungs, it stagnates in the right cavities of the heart; the superior vena cava, the internal jugulars, and consequently the sinuses of the dura mater, and the veins of the brain which terminate in them, are gradually distended; and if this dilatation were carried to a certain degree, the veins of the brain, placed between it and the arch of the skull, would tend to depress it towards the base of that cavity. If this dilatation, at first sight, were carried beyond the extensibility of these vessels, their rupture would occasion fatal effusions. It is in this manner that some authors have explained sanguineous apoplexy.

It will be objected, perhaps, that many of the sinuses of the dura mater are at the base of the skull; and that consequently their dilatation must tend to raise the cerebral mass.

But the greater part of these sinuses are connected only with the cerebellum and the medulla oblongata, of which it has not yet been possible to ascertain the motions. These sinuses are almost all lodged in the edges of the falx and of the tentorium cerebelli. The cavernous sinus in which the ophthalmic vein disgorges itself, the communicating sinuses which allow the blood of one of these sinuses to pass into the other, are too insignificant to produce a raising of the cerebral mass. Lastly, the resistance of their parietes, formed chiefly by the dura mater, must set strait bounds to their dilatation; the spongy tissue which fills the interior of the cavernous sinuses makes this dilatation and the reflux of the blood still more difficult.

CL. *Experiments shewing the cause of the brain's motion.*—It is not enough to prove, by reasons drawn from the disposition of parts, that the motions of the brain are communicated to it by the collection of arteries at its base; the fact must yet be established upon observation, and placed beyond doubt by positive experiments. The following are what I have attempted for this purpose:—

A. I have first repeated the observation of some authors, and ascertained, as they did, that the pulsations felt on placing the finger on the fontanels of the skulls of new-born infants, correspond perfectly to the beatings of the heart and arteries.

B. A patient trepanned for fracture, with effusion on the dura mater, enabled me to see the brain alternately rising and falling. The rising corresponded with the diastole, the falling with the systole of the arteries.

C. Two dogs, trepanned, exhibited the same phenomenon, in the same relation to the dilatation and contraction of the arteries.

D. I removed carefully the arch of the skull from the body of an adult. The dura mater, disengaged from its adhesions to the bones which it lines, was preserved perfectly untouched. I afterwards laid bare the main carotids, and injected them with water. At every stroke of the piston the brain shewed a very sensible motion of rising, especially when the injection was forced at once along the two carotids.

E. I injected the internal jugular veins,—the cerebral mass remained motionless; the veins of the brain only, and the sinuses of the dura mater, were dilated. The injection having been kept up for some time, there resulted from it a slight swelling of the brain: when driven with more force, some of the veins burst, and the liquor flowed out. The same injection being made with water strongly reddened, the surface of the brain became coloured with an intense red. To see clearly this effect, you ought, after removing the arch of the skull, to divide on each side the dura mater, on a level with the circular incision of the skull, then turn back the flaps towards the upper longitudinal sinus.

F. The internal jugular veins having been laid open while the injection was forced along the main carotids, each time the piston was pushed forward the venous blood flowed with the greatest impetus; a clear proof of the manifest influence of the motions of the brain on the course of the blood in its veins, and in the sinuses of the dura mater. This experiment had been already performed by other anatomists, and amongst others by Ruysch, with a view of proving the immediate communication between the arteries and veins. This communication, which is at present universally acknowledged, may be proved by other facts. This one is evidently any thing but conclusive.

G. In a trepanned dog, I tied successively the two carotids. The motions of the brain abated, but did not cease. The anastomoses of the vertebrals with the branches of the carotids account for this phenomenon.

H. I took a rabbit, a gentle creature, easy to confine, and very well adapted for difficult experiments: after laying bare the brain, and observing that its motions were simultaneous to the beats of the heart, I tied the trunk of the ascending aorta: the moment the blood ceased rising to the head, the brain ceased moving, and the animal died.

I. The tying of the internal jugular veins did not stop the motion of the brain; but its veins dilated, and its surface, bared by the removal of a flap of the dura mater, was sensibly redder than in the natural state. The dog became affected with stupor, and expired in convulsions.

The opening of these veins did not hinder the continuance of the motions; they grew fainter only when the animal was weakened by loss of blood.

K. The opening of the superior longitudinal sinus, the only one that could easily be opened, did not weaken the motions of the brain. It is observed that the blood flows out more freely from it during the elevation.

L. The compression of the thorax on human bodies produces but a slight reflux in the jugular veins, especially if, during this compression, the trunk is kept raised. The reflux is greater when the trunk is laid flat.

These experiments might be varied and multiplied: if, for instance, the injection were thrown at once along the vertebral arteries and the internal carotids; but those I have stated are sufficient for my purpose.

Since the first publication of this inquiry, in the Memoirs of the Medical

Society,* I have had many opportunities of repeating the observations and experiments, which serve as a foundation to the theory there detailed. Among the facts which confirm this theory, there is one that appears to me worth stating: it would be sufficient by itself, if it were possible to establish a theory on the observation of a single fact. A woman, about fifty years of age, had an extensive carious affection of the skull; the left parietal bone was destroyed in the greatest part of its extent, and left uncovered a pretty considerable portion of the dura mater. Nothing was easier than to ascertain the existence of a complete correspondence between the motions of the brain and the beats of the pulse. I desired the patient to cough, and to suspend her respiration suddenly; the motions continued in the same relation to each other: when she coughed, the head was shaken, and the general concussion, in which the brain partook, might have been mistaken by a prejudiced observer for the proper motions of that organ, and depending on the reflux of blood in the veins.

In experiments on dogs, the same motion takes place when the animal barks; but it is easy to perceive, that the concussion affecting the brain is experienced by the whole body, and that the effort of expiration in barking causes a concussion more or less violent.

The patient mentioned in the preceding observation died about a month after I came to the Hospital of St. Louis, in which she had been for a considerable length of time. On opening the body, the left lobe of the brain was found softened and in a kind of putrid state; the ichor, which was formed in considerable quantity, flowed outwardly, by a fistulous opening in the dura mater, whose tissue was rather thickened.

CLI.—The slight consistence of the brain, which Lorry considers as favourable to the communication of the motion which its arteries impart to it, appears to me to be against this transmission. In fact, the dilated vessels not being able to depress the base of the skull on which they rest, make their effort against the cerebral mass, and raise it the more easily (the arch of the skull being removed) from its presenting a certain resistance. If the brain were too soft, the artery would merely swell into it, and would not lift it. To satisfy oneself of this truth, one need only observe what happens when the posterior part of the knee rests on a pillow, or on any thing of the same sort; then, the motions which the popliteal artery impresses on the limb are but little apparent, but they become very visible if the ham rests on any thing that offers a certain resistance, as on the knee of the opposite side, for instance; then the artery, which cannot depress it, exerts its whole action in raising the lower extremity, which it does the more easily from acting against a bony, resisting, and hard part. This experiment completely invalidates the opinion of Lorry. The want of analogy will not be objected; it will not be said that the brain is heavier than the lower extremity, nor that the sum of the calibres of the internal carotid and the vertebral arteries is not greater than that of the popliteal artery.

This continual tendency of the brain to rise, produces in the end, on the bones of the skull which resist this motion, very marked effects. Thus, the interior surface of these bones, smooth in early life, becomes furrowed with depressions, the deeper as we advance in age. The digital depressions and the mammillary processes, corresponding to the convolutions and windings of the brain, are very evidently the result of its action on the enclosing parietes. Sometimes it happens, that at a very advanced age the bones of the skull are so thinned by this internal action, that the pulsations of the brain become perceptible through the hairy scalp.

* Mémoires de la Société Médicale de Paris, troisième année, tom. iii. p. 197, *et suiv.*

No doubt the same cause hastens the destruction of the skull by the fungous tumours of the dura mater. The effort from expansion of the tumour, which developes itself, is further added, and makes the waste of the bones more rapid. At the end of a few months the tumour projects outwardly, with pulsations plainly simultaneous to the beatings of the pulse, as Louis observes in a memoir inserted among those of the Academy of Surgery.

I have shewn (CXLIX.) that the disposition of the veins of the brain and of the sinuses of the dura mater was adverse to the action ascribed to them on this viscus. Experiment (E, L) shews that the stagnation of the blood, or even its regurgitation, could produce only a slow and gradual distension of the sinuses of the dura mater and veins terminating in it, with a slight turgescence of the cerebral mass, if the cause producing the stagnation of the blood or its reflux, prolonged its action to a partial destruction of the skull.

Lastly, the alternate motions of the brain, said to correspond to those of respiration, ought to be to the beats of the pulse in the ordinary ratio of 1 to 5. On the contrary, it is easy to satisfy oneself that these motions are in an inverse ratio, and perfectly simultaneous to the pulsations of the heart and arteries.

The results of the experiments I have stated in that memoir, compared to those obtained by justly celebrated inquirers, are too remarkably different not to have induced me to make some attempt at investigating the cause of our disagreement. For that purpose I thought it necessary to examine scrupulously all the circumstances.

The work of Lamure contains anatomical errors, which throw suspicions upon his accuracy. Haller did not himself make the experiments of which he speaks in treating of the influence of respiration on the circulation of venous blood. This article is drawn from a thesis defended at Gottingen by one of his disciples. Lastly, Vicq-d'Azyr attempted no confirming experiment, and seems to have had in view only the reconciling all opinions.

No one of these anatomists has distinguished the motions of elevation impressed on the cerebral mass by the impulse of its arteries, from the swelling of the sinuses of the dura mater, of the veins distributed to it, and from the tumefaction of the brain which may be caused by difficult respiration. This mistake would be the more easy, as animals tortured by the knife of the anatomist breathe painfully, convulsively, and at shorter intervals than in their natural state. Schlitting, the first author of these experiments, appears especially to have confounded the motion of rising, the real displacement of the brain, with the turgescence of this viscus. At every expiration, he says, I have seen the brain rise, that is to say, swell, and at every inspiration I have seen it fall, that is to say, collapse.

"*Toties animadverti perspicuè, in omni expiratione cerebrum universum ascendere, id est intumescere; atque in quâvis inspiratione illud descendere, id est detumescere.*"

We may therefore consider as a truth, strictly demonstrated by observation, experiment, and reasoning, the following proposition:—

The motions observable in the brain, when laid bare, are imparted to it solely by the pulsations of the arteries at its base, and are perfectly simultaneous to the pulsations of these vessels: further, the reflux and stagnation of the venous blood are able to swell its substance.

CLII. *Action of the nerves and brain.*—It is undoubtedly, as Vicq-d'Azyr has said, by a motion of some sort that the nerves act. Setting out from this simple idea, one may admit several kinds of nervous motions, the one operating from the circumference to the centre—(it is the motion of sensation which

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we are about more particularly to study in this paragraph)—the other acting from the centre to the circumference; and this motion, produced by the will, determines the action of the muscular organs, &c.

In what manner are the impressions produced on the senses by the bodies which surround us, transmitted, along the nerves, to the brain? Is it through the intervention of a very subtle fluid? or can the nerves, as has been stated by some physiologists, be considered as vibrating cords? This last idea is so absurd, that one cannot help wondering it should so long have been in vogue. A cord, that it may vibrate, must be in a state of tension along the whole of its length, and fixed at both extremities. The nerves are not in a state of tension: their extremities, in no degree fixed, approach towards each other or recede, according to the difference of position, the tension, the turgescence, the fulness or collapse of parts, and vary constantly in their distance from each other. Besides, the nervous cords, situated between pulps at their origin and at their termination, cannot be extended between these two points. The nervous fibre is the softest, the least elastic of all the animal fibres: when a nerve is divided, its two extremities, far from receding by contracting, project, on the contrary, beyond each other; the point of section shews a number of small granulations of medullary and nervous substance, which flows through its minute membranous canals. Surrounded by parts to which they are, to a certain degree, united, the nerves could not vibrate. Lastly, admitting the possibility of their being capable of vibrating, the vibration of a single filament ought to bring on that of all the rest, and carry confusion and disorder in every motion and sensation.

It is much more probable that the nerves act by means of a subtle, invisible, and impalpable fluid, to which the ancients gave the name of animal spirits: this fluid, unknown in its nature, and to be judged of only by its effects, must be wonderfully subtle, since it eludes all our means of investigation. Does it entirely proceed from the brain, or is it equally secreted by the membranous envelopes of each nervous filament? (*Neurilèmes*, Reil.) To say the truth, one can bring no other proof of the existence of a nervous fluid, but the facility with which, by means of it, we are enabled to explain the various phenomena of sensation. This proof, however, may not appear completely satisfactory to those who are very strict, and who do not consider as proved what is merely probable.

Among the constituent principles of the atmosphere there are generally diffused several fluids, such as the magnetic and electric fluids. Might not these fluids, on entering with the air into the lungs, combine with the arterial blood, and be conveyed, by means of it, to the brain or to the other organs? Does not the vital action impart to them new qualities, by making them undergo unknown combinations? Do caloric and oxygen enter into these combinations which endow fluids with a certain vitality, and produce on them important changes, and which are not understood?* Have not these conjectures acquired a certain degree of probability, since the analogy of galvanism to electricity, at first supposed by the author of this discovery, has been confirmed by the very curious experiments of Volta, repeated, commented, and explained by all the natural phylosophers of the present day in Europe?†

The action of the nervous fluid takes place from the extremity of nerves to-

* Were it not for these changes, electricity, magnetism, and galvanism, would suffice to restore life to an animal recently dead.

† Galvanism, as yet, has not realised the expectations of physiologists. Chemistry has derived the greatest advantages from it. It is, at present, with MM. Davy, Thenard, and Gay-Lussac, the most powerful agent in the analysis of certain bodies.

wards the brain, so as to produce the phenomena of sensation; for when the nerves are tied, the parts below the ligature lose the power of sensation; while, as will be seen in the proper place, this action is propagated from the brain towards the nervous extremities, and from the centre to the circumference, in producing motions of every kind. This double current, in contrary directions, may take place in the same nerves, and it is not necessary to arrange the nerves into two classes of sensation and of motion.

All the impressions received by the organs of sense and by the sentient extremities of nerves, are transmitted to the cerebral mass. The brain is, therefore, the centre of animal life; all sensations are carried to it; it is the spring of all voluntary motion: this centre is to the functions of relation as the heart to the functions of nutrition. One may say of the brain as of the heart, *omnibus dat et ab omnibus accipit*,—it receives from all, and gives to all.*

The medullary mass enclosed in the cranium appears to be formed of two apparatuses of a different nature. In the parts lodged at the base of the cranium, and which have received from anatomists the name of *medulla oblongata*, especially resides the nervous energy which presides over muscular motions. According to recent experiments, the principle of inspiratory motion should have its seat in that part of the medulla oblongata whence proceed the eighth pair of nerves. The superior portions of the medullary mass seem to be especially destined to the exercise of intelligence. No part of these superposed, and, I may say, superadded organs, is more fully developed than in man. There is no animal who has so voluminous hemispheres as he, covering not only as they do all the rest of the encephalic mass, but also elevating and pushing before them the anterior portion of the cranium which surmounts the face, or rather which forms its frontal region. This anterior developement of the brain seems so truly characteristic of the human species, that certain philosophers have not hesitated to place in it the faculty by which man forms abstract ideas of the Divinity. There, according to the theory of Gall, is lodged the organ of theosophy. But in what manner, or by what means does the will act, in producing the various movements? What ties connect the sensations with the powers of volition? These questions are unanswerable in the present state of our knowledge; and the chief desiderata of this department of physiological science are yet to be supplied, namely, to determine, in a precise manner, the functions which belong to the different portions of the brain and of its central apparatus; likewise, whether the nervous energy proceeds from the nerves themselves, is inherent in their structures, and is the result of their action; or are they only the simple conductors and distributors of it from the sources at which they derive their origin?

The existence of a centre, to which all the sensations are carried, and from which all motions spring, is necessary to the unity of a thinking being, and to the harmony of the intellectual functions. But is this seat of the principle of motion and of sensation circumscribed within the narrow limits of a mathematical point? or rather should it not be considered as diffused over nearly the whole brain? The latter appears to me the more probable opinion: were it otherwise, what could be the use of those divisions of the organ into several internal cavities? what could be the use of those prominences, all varying in their form; and of the arrangement of the two substances which enter into their structure? We may conjecture, with considerable probability, that each perception, each class of ideas, each faculty, is assigned to some peculiar part of the brain. It is, indeed, impossible to determine the

* See APPENDIX, Notes H H.

peculiar functions of each part of the organ; to say what purpose is served by the ventricles, what is the use of the commissures, what takes place in the peduncles; but it is impossible to study an arrangement of such combination and to believe that it is without design, and that this division of the cerebral mass into so many parts, so distinct, and of such various forms, is not relative to the different function which each has to fill in the process of thought. That ingenious comparison, mentioned in the panegyric of Mery, by Fontenelle, is very applicable to the brain. "We anatomists," he once said to me, "are like the porters in Paris, who are acquainted with the narrowest and most distant streets, but who know nothing of what takes place in the houses." What, then, are we to think of the system of Gall, and of his division of the outside of the skull into several compartments, which, according to the depression or projection of the osseous case, indicate the absence or the presence of certain faculties, moral or intellectual? I cannot help thinking, that this physiological doctrine of the functions of the brain, resting on too few well-observed facts, is frivolous; while his anatomical discoveries on the anatomy of this organ, and on the nervous system, are of the highest importance and well founded.

CLIII. *Analysis of the understanding.*—In vain were the organs of sense laid open to all impressions of surrounding objects; in vain were their nerves fitted for their transmission: these impressions were to us as if they had never been, were there not provided a seat of consciousness in the brain; for it is there that every sensation is felt. Light, and sound, and odour, and taste, are not felt in the organs they impress; it is the sensitive centre that sees, and hears, and smells, and tastes. You have only to interrupt, by compression of the nerves, the communication between the organs and the brain, and all consciousness of the impressions of objects, all sensation is suspended.

The torturing pains of a whitlow cease if you bind the arm so strongly as to compress the nerve which carries the sensation to the brain. A living animal under experiments suffers nothing from the most cruel laceration, if you have first cut the nerves of the parts on which you are operating. To conclude, the organs of sense, and the nerves which communicate between them and the brain, shall have suffered no injury, shall be in a perfect state for receiving and transmitting the sensitive impression, yet no phenomena of sensation can take place if the brain be diseased—when it is compressed, for instance, by a collection of fluid, or by a splinter from the skull in a wound of the head. This organ is, therefore, the immediate instrument of sensations, of which impressions made on the others are only the occasional causes. This modification of sensibility, which serves to establish the relations of the living being with objects without, would be correctly denominated *cerebral sensibility;* but that even in animals without brain, or distinct nervous system, it is very manifest. The sensibility in virtue of which the polypus dilates his cavity for the admission of his prey, and contracts itself to retain it, is in fact quite distinct from that *sensibility of nutrition* by which its substance is enabled to take to itself nutritious juices.

The brain, as Cabanis has well expressed it, acts upon the impression transmitted by the nerves, as the stomach upon the aliments it receives by the œsophagus: it does, in its own way, digest them: set in motion by the impulse it receives, it begins to re-act; and that re-action is the *perceptive sensation*, or perception. From that moment the impression becomes an idea, it enters as an element into thought, and becomes subject to the various combinations that are necessary to the phenomena of understanding.*

* I ought to observe, that the terms thought and understanding are, in my opinion, synony-

CLIV. *Sources of our ideas.*—Our sensations are nothing but modifications of our being; they are not qualities of the objects: no body has colour to the blind from birth: the rose has lost its most precious quality to him who has lost his smell; he knows it from the anemone only by its colour, its figure, &c. We perceive nothing but within ourselves. It is only by habit, only by applying different senses to the examination of the same object, that we are at last able to separate it from our own existence; to conceive of it as distinct from ourselves, and from the other bodies with which we are acquainted; in a word, to refer to outward objects the sensations that take place within ourselves. Our ideas come to us only by the senses; there are none innate, as was imagined till the time of Locke, who has allotted to the refutation of this error a large part of his valuable work on the Human Understanding.* The child that opens its eyes to the light is prepared for the acquisition of ideas by this merely, that it is provided with an organic apparatus susceptible of impressions from the objects that surround it.

The brain pre-exists the ideas, as the eye the sensations of sight. Every where the existence of the organ precedes the exercise of its functions. It is thus as impossible to conceive thought without a brain as vision without the organ destined to receive the impression of light.

It is inaccurate, however, to compare, as some philosophers have done, the brain of a child new-born to a blank tablet, on which are to be figured all the future acts of his intelligence. If sensation came only from without, if the external senses were the only organs that could send impressions to the cerebral centre—the understanding, at the moment of birth, had indeed been nothing, and the comparison of its organ to a sheet of white paper, or to a slab of Parian marble, on which not a character was drawn, had been perfectly correct. But we are compelled to acknowledge, with Cabanis, two sources of ideas quite distinct from each other, the external senses and the internal organs. These inward sensations, springing from functions that are carrying on within us, are the cause of those instinctive determinations by which the new-born child seizes the nipple of its mother, and sucks the milk by a very complicated process; which directs the young of animals the moment after birth, and sometimes in the very act of birth, while the limbs are yet engaged in the vagina, to seize upon the dug of their dam. Instinct, as the author just quoted has very correctly observed, springs from impressions received by the interior organs, whilst reasoning is the produce of external sensations; and the etymology of the word instinct, composed of two Greek words, signifying " to prick," and " within," agrees with the meaning we assign to it.

These two parts of the understanding, reason and instinct, unite and blend together to produce the intellectual system, and the various determinations of mental action. But the part that each bears in the generation of ideas is very different in animals, whose grosser external senses allow instinct to predominate, and in man, in whom the perfection of these senses and the art of signs, which perpetuate the transient thought, augment the power of reason while they enfeeble instinct. It is easy to conceive that the brain, assailed by a crowd of impressions from without, will regard less attentively, and therefore suffer to escape, the greater part of those that result from internal excitation. Instinct is more vigorous in savage man, and its relative per-

mous; both are alike an abridged expression of the whole of the operations of the sensitive centre.

* See the APPENDIX, Notes H H, for some remarks upon Locke's account of the origin of our ideas, and upon the manner in which he has been misunderstood, or his opinions misconstrued, and even perverted, by several modern writers.—*J. C.*

fection is his compensation for the advantages which superior reason brings to man in civilisation. The moral and intellectual system of the individual, considered at different periods of life, owes more to internal sensation the less it is advanced; for instinct declines as reason is strengthened and enlarged.

Thus, though all the phenomena of understanding have their source in physical sensibility, this sensibility being set in action by two sorts of impressions, the brain of an infant just born has already the consciousness of those which spring from the internal motion, and it is from these impressions that it executes certain spontaneous movements, of which Locke and his followers could find no explanation: accordingly, the partisans of innate ideas looked upon them as the strongest confirmation of their system. But these ideas, anterior to all action of outward objects on the senses, are simple, few, and extending to a very small number of wants: the child is but a few hours old, and already it expresses a multitude of sensations that throng upon it from the instant of its birth—sensations which have passed to the brain, combined themselves there, and entered into the action of the will with a velocity which equals, if it does not surpass, that of light.

It is only after laying down between the sources of our knowledge a very exact line of demarcation,—after scrupulously distinguishing the rational from the instinctive determinations,—acknowledging that age, sex, temperament, health, disease, climate, and habit, which modify our physical organisation, must, by a secondary effect, modify these last,—that we can possibly understand the diversity of humours, of opinions, of characters, and of genius. He who has well appreciated the effect on the judgment and reason of the sensations that spring from the habitual state of the internal organs, sees easily the origin of those everlasting disputes on the distinction between the sensitive and the rational soul; why some philosophers have believed man solicited for ever by a good or an evil genius—spirits which they have personified under the names of Oromazes and Arimanes, betwixt whom they imagined eternal war; the contest of the soul with the senses, of the spirit with the flesh, of the concupiscent and irascible with the intellectual principle,—that contradiction which St. Paul laboured under, when he said, in his epistle to the Romans, that his members were in open war with his reason. These phenomena which suggest the conception of a two-fold being (*homo duplex*, Buffon) are nothing but a necessary strife betwixt the determinations of instinct and the determinations of reason—between the often times imperious wants of the organic nature, and the judgment which keeps them under, or deliberates on the means of satisfying them without offending received ideas of fitness, of duty, of religion, &c.*

CLV. *Of perception, attention, memory, imagination, reasoning, &c.*—A being absolutely destitute of sensitive organs would possess only the existence of vegetation: if one sense were added, he would not yet possess understanding, because, as Condillac has shewn, the impressions produced on this only sense would not admit of comparison; it would end in an inward feeling, a perception of existence, and he would believe the things which affected him to be a part of his being. The fundamental truth, so completely made out by modern metaphysicians, is found distinctly stated in the writings of Aristotle;† and there is room for surprise that that father of philosophy should have merely recognised it, without conforming to its doctrines; but still more that it should have been for so many ages disregarded by his successors. So absolutely is sensation the source of all our knowledge, that even the measure

* For some remarks on Instinct, see APPENDIX, Notes H H.

† *Nil est in intellectu quod non priùs fuerit in sensu:—Nisi intellectus ipse*, as Leibnitz has very justly added. See APPENDIX, Notes H H.

of understanding is according to the number and perfection of the organs of sense; and that by successively depriving the intelligent being of them, we should lower at each step his intellectual nature; whilst the addition of a new sense to those we now possess, might lead us to a multitude of unknown sensations and ideas, would disclose to us in the beings we are concerned with a vast variety of new relations, and would greatly enlarge the sphere of our intelligence.

The impression produced on any organ by the action of an outward body does not constitute sensation; it is further requisite that the impression be transmitted to the brain, that it be there *perceived*, that is, felt by that organ; the *sensation* then becomes *perception*, and this first modification supposes, as is apparent, a central organ, to which the impressions on the organs of sense may be carried. The cerebral fibres are more or less disturbed by the sensations sent to them at once from all the organs of sense; and we should acquire but confused notions of the bodies from which they proceed, if one stronger perception did not silence as it were the rest, and fix the *attention*. In this concentration of the soul upon a single object, the brain is feebly stirred by many sensations that leave no trace; it is thus that after the attentive perusal of a book, we have lost the sensations that were produced by the different colour of the paper and the letters.

When a sensation is of short duration, our knowledge of it is so slight that soon there remains no remembrance of it. It is thus that we do not perceive every time we wink that we pass from light to darkness, and from darkness to light. If we fix our attention on this sensation, it affects us more permanently. After occupying oneself for a given time with a number of things, with but moderate attention to each—after reading, for instance, a novel, full of events, each of which in its turn has interested us, we finish it without being tired of it, and are surprised at the time it has taken up. It is because successive and light impressions have effaced one another, till we have forgotten all but some of the principal actions. Time ought then to appear to us to have passed rapidly; for, as Locke has well said, in his Essay on the Human Understanding, " We conceive the succession of times only by that of our thoughts."

This faculty of occupying oneself long and exclusively with the same idea, of concentrating all the intellectual faculties on one object, of bestowing on the contemplation of it alone a lively and well-supported *attention*, is found in greater or less strength in different minds; and some philosophers appear to me to have explained, very plausibly, the different capacity of different minds and the various degrees of instruction of which we are capable, by the degree of attention we are able to give to the objects of our studies.

Who, more than the man of genius, pauses on the examination of a single idea, considers it with more profound reflection, under more aspects and relations, bestows on it, in short, more entire attention.

Attention is to be considered as an act of the will, which keeps the organ to one sensation, or prepares it for that sensation so as to receive it more deeply. To look is to see with attention; to listen is to hear attentively; the smell, the taste, in the same way, are fixed upon an odour or a flavour, so as to receive from them the fullest impression. In all these cases the sensation may be involuntary, but the attention by which it is heightened is an act of the will. This distinction has already been well laid down with regard to the feeling, which is only the touch exerted under the direction of the will.

According to the strength or faintness of the impression that a sensation or an idea (which is but a sensation operated upon by the cerebral organ) has produced on the fibres of that organ, will be the liveliness and permanence of

the recollection. Thus, we may have *reminiscence* of it or recall faintly that we have been so affected; or *memory*, which is a representation of the object with some of its characteristic attributes, as colour, bulk, &c.

The pains that appear to be felt in limbs which we have lost have not their place in the part that is left; the brain is not deceived when it refers to the foot the sufferings of which the cause is in the stump, after the amputation of the leg or thigh. I have at this moment before me the case of a woman and of a young man, whose leg and thigh I took off for scrufulous caries, of many years standing, and incurable by any other means. The wound from the operation is completely cicatrised. The stump has not more sensibility than any other part covered by integuments, since it may be handled without pain; and yet, both at intervals, and especially when the atmosphere is highly electrified, complain of pains in the limbs which they have lost some months ago: they recognise them, by certain characters, for those of their disease. They, like all perceptions, are manifestly given in charge to the memory, which reproduces them when the cerebral organ repeats the action once occasioned by the impressions of the disease.

Finally, if the brain is easy of excitation, and at the same time faithful in preserving the impressions it has received, it will possess the power of bringing up ideas with all their connected and collateral notions—of reproducing them, in some sort, by recalling the entire object, whilst memory presents us with a few of its qualities only. This creative faculty is called *imagination*. If it sometimes produces monsters, it is that the brain, by its power of associating, connecting, combining ideas, reproduces them in an order not according to nature, gathers them under capricious associations, and gives occasion to many erroneous judgments.

When the mind brings together two ideas, when it compares them and determines on their analogy, it *judges*. A certain number of *judgments*, in series, forms a *reasoning*. To reason, then, is only to judge of the relations that exist among the ideas with which the senses supply us, or which are produced by imagination.

It is with the faculties of the soul as with those of the body; when called into full exertion, the intellectual organ gains vigour; it languishes in too long repose. If we exercise certain faculties only, they are greatly developed, to the prejudice of the rest. It is thus that by the study of mathematics soundness of judgment and precision of reasoning are acquired, to the extinction of imagination, which never rises to great strength without injury to the judging and reasoning powers. The descriptive sciences employ especially the memory, and it is seldom that they much enlarge the minds of those who study them exclusively.

CLVI. *Of spoken signs or language.*—Condillac has immortalised his name by being the first to discover, and by demonstrating irrefragably, that signs are as necessary to the formation as to the expression of ideas; that language is not less useful for thinking than for speaking; that if we could not attach the notions once acquired to received signs, they would remain always unconnected and incomplete, since we should have no power to associate and compare them, and to determine their relations. It is the imperfection or the total want of signs for fixing their ideas, that makes the infancy of the lower animals perpetual. It is this that makes it impossible for them to transmit to another generation, or even to communicate one with another, the acquisitions of individual experience, which experience is indeed, by the same cause, restrained within very narrow limits, and confined to a few simple notions—a few ideas, resting merely on its wants and on its powers. If there were not signs to preserve ideas and to connect them, memory would be nothing: all

impressions would be effaced soon after they were felt, all collections of ideas would be dissolved as soon as formed (if they could be formed at all); our ignorance would be indefinitely prolonged, and we should reach old age with a mind still in its infancy.

When we reflect on a subject, it is not directly on the ideas, but on the words expressing them, that the mind operates; we should never have the idea of numbers if we had not assigned distinct names to numbers, whether single or collected. Locke speaks of some Americans who had no idea of the number thousand, because the words of their language expressed nothing beyond the number twenty. La Condamine informs us, in his narrative, that there are some who count only to three, and the word they employ to express the number is so complicated, of a pronunciation so long and difficult, that, as Condillac observed, it is not surprising that, having begun with a method so inconvenient, they have not been able to advance any farther. "Deny," says this writer, "to a superior mind the use of letters, how much of knowledge you put out of his reach, which an ordinary capacity will attain to without difficulty. Go on, and take from him the use of speech, the lot of the dumb will shew you how narrow are the limits within which you confine him. Finally, take from him the use of all sorts of signs, let him be unable to find the least sign for the most ordinary thought, and you have an idiot."*

We are made acquainted by travellers with certain tribes, so backward in the art of expressing their ideas by signs, that they seem to serve as a link between civilised nations and certain species of animals whose instinct has been perfected by education. One might even assert, that there is less distance, in respect to intelligence, from man in that extreme abasement to the higher animals, than there is to a man of superior genius, such as Bacon, Newton, or Voltaire.

In another part of the same work, after having demonstrated that languages are real analytic methods—that the sciences may be reduced to well-constructed languages, he shews how powerful is their influence in the cultivation of the mind. But he shall speak himself with that clearness of expression which is the characteristic and the charm of his writings. "Languages are like the ciphers of the geometricians; they present new views to the mind, and expand it as they are brought nearer to perfection. The discoveries of Newton had been prepared for him by the signs that had been already contrived and the methods of calculations that had been invented. If he had arisen sooner he might have been a great man to his own age, but he would not have been the admiration of ours. It is the same in other departments."

The most scanty languages have been formed in the most barren countries. The savage who strays along the desert shores of New Zealand needs but few signs to distinguish the small number of objects that habitually impress his senses; the sky, the earth, the sea, fire, shells, the fish that form his chief food, the quadrupeds, and the vegetables, which are but few in number under this severe climate, are all that he has to name and to know: accordingly, his vocabulary is very small; it has been given to us by travellers in the compass of a few pages. A copious language, one capable of expressing a great variety of objects, of sensations, and of ideas, supposes high civilisation in the people among whom it is spoken. You hear complaints of the perpetual recurrence of the same expressions, the same thoughts, the same images in the poetry of Ossian; but living amidst the barren rocks of Scotland, the bards could not speak of things of which nothing on the soil they inhabited could supply them with the idea. The monotony of their language was

* Essai sur l'Origine des Connoissances Humaines, sec. 4.

involved in that of their impressions, always produced by rocks, mists, winds, the billows of the ireful ocean, the gloomy heath, and the silent pine, &c. The repetition of the same expressions in the Scriptures, shews that civilisation had not made the same progress among the Hebrews as among the Greeks and Romans. The connexion there is between the genius of a language and the character of the people that speak it; the influence of climate, of government, and of manners, on language; the reason why the great writers in every department appear together at the very time in which a language reaches its perfection and maturity, &c.;—these are problems that suggest themselves, and would well merit our endeavours to obtain solution, did not the investigation manifestly lead beyond the limits of our inquiry.

Though Condillac has said repeatedly in his works, that all the operations of the soul are merely sensation variously transformed, and that all its faculties are included in the single one of sense, his analysis of thought leaves still much doubt and uncertainty on the real character and relative importance of each of her faculties.

The merit of dispersing the mist which covered this part of metaphysics remained for M. de Tracy. His Elements of Ideology,* leave nothing to be wished for on this subject. I shall extract some of its main results, referring the reader for the rest to the work.

To think is only to feel; and to feel is, for us, the same as to exist; for it is by sensation we know of our existence. Ideas or perceptions are either sensations, properly so called, or recollections, or relations which we perceive; or, lastly, the desire that is occasioned in us by these relations. The faculty of thought, therefore, falls into the natural subdivision of sensibility, properly termed memory, judgment, and will. To feel, properly speaking, is to be conscious of an impression; to remember, is to be sensible of the remembrance of a past impression; to judge, is to feel relations among our perceptions; lastly, to will, is to desire something. Of these four elements, *sensations*, *recollections*, *judgments*, and *desires*, are formed all compound ideas. Attention is but an act of the will; comparison cannot be separated from judgment, since we cannot compare two objects without judging them; reasoning is only a repetition of the act of judging; to reflect, to imagine, is to compose ideas, analysable into sensations, recollections, judgments, and desires. This sort of imagination, which is only certain and faithful memory, ought not to be distinguished from it.

Finally, want, uneasiness, inquietude, desire, passions, &c. are either sensations or desires. There is room, therefore, to reproach Condillac with having divided the human mind into understanding and will only; because the first term includes actions too unlike, such as sensation, memory, judgment; and with having run into the opposite extreme, in the too great multiplication of secondary divisions.

CLVII. *Disorders of thought.*—Philosophers would, undoubtedly, attain to a much profounder knowledge of the intellectual faculties of man, if they joined, to the study of their regular and tranquil action, that of the many disordered actions to which they are liable. It is not enough, if we would understand them aright, to watch their operation when the soul is undisturbed and at ease; we must follow it in its perturbations and wanderings; we must see its powers—now separating themselves from those with which they ought to act; now combining with them under false perceptions; sometimes altogether drooping, and sometimes starting into an extreme violence of action, of which we can neither mistake the importance nor the nature; and, as the greater part of our ideas are derived from the analogies we are able to discern

* *Elémens d'Idéologie, par M. le Comte Destutt Tracy, Membre de l'Institut.*

among the objects that supply them amidst these troubles of human passion and human reason, we learn to conceive more profoundly of their nature than if we had been satisfied with observing them in the calm of their natural condition.

The observation of mania is yet too imperfect in the number, variety, and precision of its facts, to fix the classification of the species of mental alienation according to the intellectual faculty that is disordered in each. Professor Pinel has, nevertheless, ventured to ground his distinctions of the species of mania on the labours of modern psychologists, and has shewn that all might be referred to five kinds, which he marks by the names of melancholy, of mania without delirium, mania with delirium, dementia, and idiocy.* In the first four kinds there is perversion of the mental faculties, which are in languid or excessive action. We are not to look for the cause of these derangements in vice of original conformation; for melancholy, mania with or without delirium, and madness, scarcely ever appear before puberty. It is agreed among observers, that almost all maniacs have become so between twenty and forty years old; that very few have lost their reason either before or after this stormy period of life, wherein men,—yielding by turns to the torments of love and of ambition, of fear and of hope; to the sweet illusions of happiness, and the realities of suffering; consumed with passions for ever reviving, often repressed, and rarely satisfied—feel their intellectual powers impaired, annihilated, or abused, by that tempest of the moral nature, which has well been compared to the storms that, in their violence, lay desolate the flourishing earth.

We are compelled to grant, that our acquaintance with the structure of the brain and of the nerves is too imperfect, that dissections of the bodies of maniacs have been too few, and those often by physicans* too little familiar with the minute structure of the sensitive organ, to warrant us in asserting or denying that derangement of intellect depends constantly on organic injury; and though it is highly probable,—at least, many facts collected by observers, who, like Morgagni, deserve the utmost confidence, authorise the belief,—that the consistence of the brain is increased in some maniacs, who are distinguished by the most obstinate and unvarying adherence to their ruling ideas; that it is, on the other hand, soft, watery, and in a kind of incipient dissolution in some others, whose incoherent ideas, after their aptitude for association and for transformation into judgments is gone, succeed one another rapidly, and seem to pass away without a trace; and that certain organic lesions, such as softening of the brain, the developement of tumours, tubercles, encysted growths, &c. occasion necessary alteration of the intellectual functions.

If, in the multitude of maniacs, the organ of the understanding suffers only imperceptible injury, it is very remarkably changed in idiots. The almost entire obliteration of the intellectual faculties, which constitutes idiocy, when it is not brought on by some strong and sudden shock, some unexpected and overwhelming emotion, breaking down at once all the springs of thought—when it is an original defect—is always connected with mal-conformation of the skull, with the constraint of the organs it encloses. These defects of organisation lie, as M. Pinel observes, in the excessive smallness of the head to the whole stature, or to the want of proportion among the different parts of the skull. Thus, in the idiot whose head is given in his work on mania (pl. II. fig. 6), it is only the tenth of the whole height, whilst it

* For more ample explanation I must refer to the work, *Traité Médico-philosophique sur l'Aliénation Mentale, ou la Manie, par P. Pinel.* Paris, 1800.

† This censure is especially applicable to the researches of Dr. Greding.

should be something more than a seventh, if we take the Apollo of Belvedere as the type of the ideal perfection of the human figure. An idiot, whom I occasionally see, has the occipital extremity of the head so much contracted, that the large extremity of the oval formed by the upper face, instead of being placed at the back, as in other men, is, on the contrary, turned forwards, and answers to the forehead, which itself slopes towards the sinciput. The vertical diameter of the skull is inconsiderable. The head, thus shortened from above downwards, is much flattened on the sides. The hands and feet are very small, and often cold; the genitals, on the contrary, are extremely large.

In two other children, equally idiots, and now in the hospital of St. Louis, the skull, very large behind, ends in a contracted extremity, and the forehead is very short, and not more than two inches and a half wide, measuring from the semicircular process, which terminates the temporal fossa at the upper part, to the commencement of the same process on the other side. The excessive growth of the genitals is not less conspicuous: they are in these two children, one ten, the other twelve years old, as well as in the first of whom I spoke, who is fourteen, of larger size than is commonly seen after the appearance of puberty. There is nothing to indicate that this season is attained by these three idiots.

The same excess of growth is found more conspicuously among the cretins of the Valais, idiots who (in consequence of a weak and degraded organisation) are prone to lasciviousness and the most frequent onanism.

This sort of opposition in the relative energy of the intellectual organ and of the system of reproduction, in the developement of the brain and that of the parts of generation, is a phenomenon which must strongly interest the curiosity and engage the attention of physiologists. Who is there unacquainted with that enervation of the understanding, that intellectual and physical debility which indulgence in the pleasures of love brings on, if we exceed ever so little the bounds of scrupulous moderation? Castration modifies the moral character of men and animals, at least as powerfully as their physical organisation, as M. Cabanis has shewn, in treating of the influence of the sexes on the origin and growth of the moral and intellectual powers.*

CLVIII.—Our physical, therefore, holds our moral nature under a strict and necessary dependence; our vices and our virtues sometimes produced, and often modified, by social education, are frequently, too, results of organisation. To the conclusive proofs which the philosopher I have just named, who is an honour to his profession, brings forward of the influence of the physical on the moral human being, I will only add a single observation. It is not certainly the first that has been made of the kind; but none such, I believe, has yet been published. The reader recollects, I have no doubt, the old woman of whom I have spoken in treating of the motions of the brain, which an enormous caries of the bones of the skull gave an opportunity of observing in her. I wiped off the sanious matter which covered the dura mater, and I at the same time questioned the patient on her situation. As she felt no pain from the compression of the cerebral mass, I pressed down lightly the pledget of lint, and on a sudden the patient, who was answering my questions rationally, stopped in the midst of a sentence; but she went on breathing, and her pulse continued to beat: I withdrew the pledget; she said nothing. I asked her if she remembered my last question; she said no. Seeing that the experiment was without pain or danger, I repeated it three times, and thrice I suspended all feeling and all intellect.

* *Des Rapports du Physique et du Moral de l'Homme.* 2 vols. 8vo.

A man trepanned for a fracture of the skull, with effusion of blood and pus on the dura mater, perceived his intellectual faculties going, the consciousness of existence growing benumbed and threatening to cease in the interval of each dressing, in proportion as the fluid collected.

There are surgical observations on wounds of the head containing several facts that may be connected with the preceding observations. There is no one who has had syncope of more or less continuance, but knows that the state is without pain or uneasiness, and leaves no consciousness of what passed whilst it lasted. It is the same after an apoplexy, a fit of epilepsy, &c.

The history of temperament supplies us with too many examples of the strict connexion which there is between the physical organisation and the intellectual and moral faculties, to leave any necessity for dwelling longer on this truth, which no one questions, but which no philosopher has yet followed into all its consequences.

CLIX. *Of the passions.*—An English writer, in a work on the history of of mental alienation,* has traced, better than had before been done, the physiological history of the passions, which he looks upon as mere results of organisation, ranking them among the phenomena of the animal economy, and with abstraction of any moral notion that might attach to them.

All passion is directed to the preservation of the individual or the reproduction of the species. They may be distinguished, therefore, like the functions, into two classes.† In the second, we should find parental love, and all the affections that protect our kind through the helplessness of its long infancy.

But Crichton, with the greater part of metaphysicians and physiologists, appears to me not to have settled correctly the meaning that should belong to the word passion. When he gives this name to hunger, an inward painful sensation, the source of many determinations of many kinds—a powerful mover of savage and civilised man; to the anxiety which attends the breathing an air deficient in oxygen; to the impressions of excessive heat and cold; to the troublesome sensations produced by the accumulation of urine and fæcal matter; to the feeling of weariness and fatigue that is felt by violent exertions;—he confounds sensation with the passions or desires which may spring from it.

It is to avoid extreme wants, of which a vigilant foresight perceives afar off the possibility; it is to satisfy all the factitious wants which society and civilisation have created, that men condemn themselves to those agitations, of which honour, reputation, wealth, and power, are the uncertain aim. Our passions have not yet been analysed with the same care as our ideas: no one has yet duly stated the differences there are, in respect to their number and energy, betwixt savage man and man in the midst of civilised and enlightened society.

As the habitual state of the stomach, of the lungs, of the liver, and internal organs, is connected with certain sets of ideas—as every vivid sensation of joy or distress, of pleasure or pain, brings on a feeling of anxiety in the præcordia, the ancients placed in the viscera the seat of the passions of the soul: they placed courage in the heart, anger in the liver, joy in the spleen, &c. Bacon and Van Helmont seated them in the stomach; Lecat in the nervous plexuses; other physiologists in the ganglions of the great sympathetic, &c. But have they not confounded the effect with the cause? the appetite with the passion to which it disposes? The appetites, out of which the passions spring, reside in the organs; they suppose only instinc-

* An Inquiry into the Nature and Origin of Mental Derangement. London, 1798, 2 vols. 8vo.

† See APPENDIX, Notes H H.

tive determinations, whilst passion carries with it the idea of intellectual exertion. Thus, the accumulation of semen in the vesiculæ, which serve for its reservoirs, excites the venereal appetite, quite distinct from the passion of love, though often its determining cause. Animals have scarcely more than appetite, which differs as much from passion as instinct from intelligence. However, the brain is not to be considered as the primitive seat of the passions,* as is done by the greater number of philosophers. Of all the feelings of man, the most lasting, the most sacred, the most passionate, and the least susceptible of injury from all the prejudices of the social state, maternal love, is surely not the result of any intellectual combination, of any cerebral action: its source is in the bowels (*entrailles*); thence it springs, and all the efforts of imagination cannot attain it for those who have not been blessed with a mother's name.

All passion springs from desire, and supposes a certain degree of exaltation of the intellectual faculties. The shades of the passions are infinite: they might all be arranged by a systematic scale; of which indifference would be the lowest gradation, and maniacal rage the highest. A man without passions is as impossible to imagine as a man without desires; yet we distinguish as passionate those whose will rises powerfully towards one object earnestly longed for. In the delirium of the passions, we are for ever making, unconsciously, false judgments, of which the error is exaggeration. A man recovering from a seizure of fear, laughs at the object of his terror. Look at the lover whose passion is extinct! freed at last from the spell that enthralled him, all the perfections with which his love had invested its object are vanished: the illusion has passed away; and he can almost believe that it is she who is no longer the same, while himself alone is changed: like those maniacs who, on their return to reason, wonder at the excesses of their delirium, and listen incredulously to the relation of their own actions. The ambitious man feeds on imaginations of wealth and power. He who hates, exaggerates the defects of the object of his hatred, and sees crimes in his slightest faults.

The *affections* of the soul, or the passions, whether they come by the senses, or some disposition of the vital organs favour their birth and growth, may be ranged in two classes, according to their effects on the economy. Some heighten organic activity; such are joy, courage, hope, and love; whilst others slacken the motions of life, as fear, grief, and hatred. And others there are that produce the two effects alternately, or together. So ambition, anger, despair, pity, assuming, like the other passions, an infinite variety of shades, according to the intensity of their causes, individual constitution, sex, age, &c. at times increase, at times abate the vital action, and depress or exalt the power of the organs.

The instances which establish the powerful influence of the passions on the animal economy, are too frequent to need reciting. Writers in every department furnish such as shew that excess of pleasure, like excess of pain,—joy too lively or too sudden, as grief too deep and too unexpected, may bring on the most fatal accidents, and even death. Without collecting in this place all the observations of the sort with which books swarm, I shall content myself with referring to those who have brought together the greatest number of facts under one point of view; as Haller, in his Physiology; Tissot, in his

* If we analysed the passions carefully, it would be right to distinguish those which are common to all men—which appertain to our physical wants and to our nature—from certain caprices of the mind which have been honoured with the name of passions, as avarice, ambition, &c. which should be referred to kinds of mental derangement, and classed as species of monomania.

Treatise on Diseases of the Nerves; Lecamus, in his work on Diseases of the Mind; and Bonnefoy, in a paper on the Passions of the Soul, inserted in the fifth volume of the Collection of Prizes adjudged by the Academy of Surgery.

The effects of the passions are not, for their uniformity, the less inexplicable. How, and why does anger give rise to madness, to suppression of urine, to sudden death? How does fear determine paralysis, convulsions, epilepsy, &c.? Why does excessive joy—a sense of pleasure carried to extremity—produce effects as fatal as sad and afflicting impressions? In what way can violence of laughter lead to death? Excess of laughter killed the painter Zeuxis, and the philosopher Chrysippus, according to the relation of Pliny. The conversion of the reformed of the Cevennes, under Louis XIV., was effected by binding them on a bench, and tickling the soles of their feet, till, overpowered by this torture, they abjured their creed: many died in the convulsions and immoderate laughter which the tickling excited.* A hundred volumes would be insufficient to detail all the effects of the passions on physical man: how many would it take to tell their history in moral man, from their dark origin through all their stages of growth, in the infinite variety of their characters, and in all their evanescent shades!

The inquiries of Physiology are directed to the functions that are carried on in physical man—to the functions of life: the study of the nobler parts of ourselves, of those wonderful faculties which place our kind above all that have motion or life; in a word, the knowledge of moral and intellectual man, belongs to the science known by the name of metaphysics, or psychology,—of analysis of the understanding; but better described by that applied to it by the writers of our days, ideology, or the science of ideas. On this science you may consult with advantage the philosophical works of Plato and Aristotle, among the ancients; of Bacon, Hobbes, Locke, Condillac, Bonn, Smith, Reid, Dugald Stewart, Brown, Cabanis, and Tracy, among the moderns.

CLX. *Of sleep and waking.*—The causes of excitation to which our organs are exposed during waking, tend to increase progressively their action: the pulsations of the heart, for instance, are much more frequent in the evening than in the morning; and this motion, gradually accelerated, would soon be carried to a degree of activity incompatible with the continuance of life, did not sleep daily temper this energy, and bring it down to its due measure. Fever is occasioned by long-continued want of sleep; and in all acute diseases the exacerbation comes on towards evening; the night's sleep abates again the high excitation of power: but this state of the animal economy, so salutary and so desirable in all sthenic affections, is more injurious than useful in diseases consisting chiefly in extreme debility. Adynamia shews itself almost always in the morning in putrid fevers; and petechiæ, a symptom of extreme weakness, break out during sleep. This state is likewise favourable to the coming on and to the progress of gangrene; and this is a pathological fact well ascertained. In all the cases I have mentioned sleep does not improve the condition of the patients; a thing easy to conceive, since it only adds to accidental debility, the essential characteristic of the disease, weakness, which is also its principal characteristic.

Sleep, that momentary interruption in the communication of the senses with outward objects, may be defined the repose of the organs of sense and of

* This instance, however, does not illustrate the influence of the passions on the vital functions. It shews merely the effects of irritation of the extremities of nerves upon the functions of other nerves, either of the same, or of a different order, which effects are either produced by a direct medium of communication with the nerves first affected, or then by means of the nervous centres.—*J. C.*

voluntary motion. During sleep, the inward or assimilating functions are going on: digestion, absorption, circulation, respiration, secretion, and nutrition, are carried on; some, as absorption and nutrition,* with more energy than during waking, whilst others are evidently slackened. During sleep the pulse is slower and weaker, inspiration is less frequent, and insensible perspiration, urine, and all other humours derived from the blood, are separated in smaller quantity. Absorption is, on the contrary, very active: hence the danger of falling asleep in the midst of a noxious air. It is known that the marshy effluvia, which makes the Campagna di Roma so unhealthy, brings on, almost inevitably, intermittent fevers, when the night is passed there, whilst travellers who go through without stopping, are not affected by it.†

The human body is a tolerable representation of the *centripetal* and *centrifugal* powers of ancient physics. The motion of many of the systems which enter into its structure is directed from the centre to the circumference: it is a real exhalation that carries out the result of the perpetual destruction of the organs; such is the action of the heart, of the arteries, and of all the secretory glands. Other actions, on the contrary, take their direction from the circumference to the centre; and it is by their means that we are incessantly deriving from the food we take into the digestive passages, and from the air which penetrates the interior of the lungs, and covers the surface of the body, the elements of its growth and repair. These two motions, in opposite directions, continually balance each other, prevailing by turns, according to the age, the sex, and the state of sleep or waking. During sleep the motions tend from the periphery to the centre (Hipp.); and if the organs that connect us with outward objects are in repose, the inward parts are in stronger exertion.‡ A man, aged forty years, taken with a kind of imbecility, remained about a year and a half at the Hospital of St. Louis, for the cure of some scrofulous glands. All that long time he remained constantly in bed, sleeping five-sixths of the day, tortured with devouring hunger, and passing his short moments of waking in eating: his digestion was always quick and easy; he kept up his plumpness, though the muscular action was extremely languid, and the pulse very weak and very slow. In this man, who, to use the expression of Bordeu, lived under the dominion of the stomach, the moral affections were limit-

* Nutrition is evidently more active during sleep, in early life, especially in childhood; and, in many constitutions and habits of body, it appears equally active, during this state, through the middle stages of life; but as soon as the period of decay approaches, absorption appears to predominate, while, on the contrary, nutrition gradually languishes more and more, during sleep, as age advances. In the middle periods of existence it is difficult to determine whether absorption or nutrition is augmented during this state: the difference cannot always be correctly appreciated; but we generally find that when the one is increased the other is diminished, both functions being seldom augmented or impaired at the same time.—*J. C.*

† This is quite as much the result of the low state of the nervous or vital energy of the system during sleep. The vital powers at that time are not under the impression of the excitements communicated through the medium of the nerves of sensation and motion; the operations, indeed, of this part of the nervous system are for a time suspended, and consequently the vital functions lose part of their energy, and are open to the influence of such causes of disease as generally invade them during states of debility and exhaustion, or when they are not otherwise acted on either by external or internal stimuli.

It may be justly asserted, that the operations of the system languish in a degree proportionate to that in which they are deprived of their natural excitements, whether these excitements are food, air, exercise, amusement, &c.—whether they are corporeal or mental—or whether they are external or internal in respect of their modes of existence and their manner of operation on the body. When, therefore, the system is deprived of a part of these excitements—of the influences of the mental operations, and of the excitements of sensation and voluntary motion, as it is during sleep, its operations are necessarily more languid and weak, and consequently it is more readily impressed by many of the causes of disease, especially by those which are usually productive of fever, than during the waking state. The condition of the night air in respect of temperature, and the concentration of the moisture and of the terrestrial exhalations in the lower regions of the atmosphere, especially in particular situations, also contribute to the effect mentioned in the text.—*J. C.*

‡ *Somnus labor visceribus.* (Hipp.)

ed to the desire of food and of repose. Oppressed with irresistible sloth, it was never without great difficulty that he could be brought to take the slightest exercise.

Waking may be looked upon as a state of effort, and of considerable expenditure of the sensitive and moving principle, by the organs of sensation and of motion. This principle would have been soon exhausted by this uninterrupted effusion, if long intervals of repose had not favoured its restoration. This interruption in the exercise of the senses and of voluntary motion, is of duration corresponding to that of their exertion. I have already said, that there are functions of such essential importance to life, that their organs could be allowed but short moments of repose; but that these intervals are brought so close to each other, that their time is equally divided between activity and repose. The functions which keep up our connexion with outward objects could not be without the capacity of continuing, for a certain time, in a state of equal activity; for it is easy to see how imperfect would have been relations interrupted at every moment: their repose, which constitutes sleep, is equally prolonged.

The duration of sleep is from a fourth to a third of the day: few sleep less than six hours, or more than eight. Children, however, require longer sleep, the more the nearer they are to the period of their birth. Old men, on the contrary, have short sleep, light and broken; as if, says Grimaud, according to Stahl's notions, children foresaw that in the long career before them, there was time enough for performing at leisure all the acts of life; while old men, near to their end, felt the necessity of hurrying the enjoyment of a good already about to escape.

If the sleep of a child is long, and deep, and still, it is the wonderful activity of the assimilating functions that makes it so, and perhaps the habit itself of sleep, in which he has passed the first nine months of his life, or all the time before his birth. In advanced age, the internal functions grow languid; their organs no longer engage the action of the principle of life; and the brain is, moreover, so crowded with ideas, that it is almost always kept awake by them. Carnivorous animals sleep longer than graminivorous, because during waking they are more in motion, and, perhaps, too, because the animal substances on which they subsist yielding them more nutritious particles from the same bulk, they have need of less time for devouring their food and providing for their subsistence.*

Sleep is a state essentially different from death, to which some authors have erroneously likened it.† It merely suspends that portion of life which serves to keep up with outward objects an intercourse necessary to our existence. One may say that sleep and waking call each other, and are of mutual necessity. The organs of sense and motion, weary of acting, rest; but there are many circumstances favouring this cessation of their activity. A continual excitation of the organs of sense would keep them continually awake; the removal of the material causes of our sensations tends, therefore, to plunge us into the arms of sleep: wherefore we indulge in it more voluptuously in the gloom and the stillness of night.‡ Our organs fall asleep

* Probably, their more powerful digestion of a more nutritious food brings into the system a copious and sudden accession of chyle, which oppresses them with sleep,—circumstances required to recruit the powers that have been exhausted by the laborious quest of food, and by the long-continued endurance of hunger.

Animal food, according to the extent to which it is indulged in, or the length of the intervals between its use, produces either absolute or relative vascular plethora, both which states dispose to sleep.—*J. C.*

† To say that sleep is the image of death, that vegetables sleep always, is to use an inaccurate and unmeaning expression. How can plants, without brain or nerves, without organs of sense, motion, or voice, sleep, when sleep is nothing but the repose of these organs?

‡ The tissue of the eye-lids is not so opaque but we may distinguish through them light from

one after the other ; the smell, the taste, and the sight, are already at rest, when the hearing and the touch still send up faint impressions. The perceptions, awhile confused, in the end disappear ; the internal senses cease acting, as well as the muscles allotted to voluntary motion, whose action is entirely subject to that of the brain.

Sleep is a state, if not altogether passive, in which at least the activity of most of the organs is remarkably diminished, and that of some of them is completely suspended. It is erroneously, then, that some authors have viewed it as an active phenomenon, and a function of the living economy : it is only a mode or manner of being. It is to no purpose they have maintained that to sleep required some measure of strength. Excessive fatigue hinders sleep merely by a sense of pain in all the muscles, a pain that excites anew the action of the brain, which it keeps awake, till it is itself overpowered by sleep.

It has been attempted to shew the proximate cause of sleep. Some have said that it depends on the collapse of the laminæ of the cerebellum ; which, as they conceive, are in a state of erection during waking ; and they argue from the experiment in which, by compressing the cerebellum of a living animal, sleep is immediately brought on. This sleep, like that produced by compression of any other part of the cerebral mass, is really a state of disease, and no more natural than apoplexy. Others, conceiving sleep, no doubt, analogous to this affection, ascribe it to the collection of humours upon the brain during waking. This organ, say they, compressed by the blood which obstructs its vessels, falls into a state of real stupor ;—an opinion as unsupported as the other. As long as the humours flow in abundance towards the brain, they keep up in it an excitement which is altogether unfavourable to sleep. Do we not know, that it is enough that the brain be strongly occupied by its thoughts, or vividly affected in any way, to repel sleep ? Coffee, and spirituous liquors in small quantities, will produce sleeplessness, by exciting the force of the circulation, and determining towards the brain a more considerable afflux of blood. All, on the other hand, that may divert this fluid towards another organ, as copious bleedings, pediluvium, purges, digestion, copulation, severe cold, or whatever diminishes the force with which the blood is driven towards the brain, as inebriation, or general debility, tends powerfully to promote sleep. In like manner, it is observed, that while sleep lasts the cerebral mass collapses ; a sign that the flow of blood into it is remarkably lessened.

The organs of the senses, laid asleep in succession, awake in the same manner. Sounds and light produce impressions, confused at first, on the eyes and ears : in a little time these sensations grow distinct ; we smell, we taste, we judge of bodies by the touch. The organs of motion prepare for entering into action, and begin to act at the direction of the will.* The causes of waking operate by determining a greater flow of blood into the brain ; they include all that can affect the senses, as the return of light and of noise, with the rising of the sun : at times they act within us. Thus, urine, fæcal matter, other fluids accumulated in their reservoirs, irritate them, and send up towards the brain an agitation which assists in dispelling slumber. Habit, too, acts upon this phenomenon, as on all those of the nervous and sensitive system, with most remarkable influence. There are many that sleep soundly amidst noises which, at first, kept them painfully awake. Whatever need he may have of longer repose, a man that has fixed the daily hour of his waking, will awake every morning to his hour. It is as much under the con-

darkness : accordingly, a lighted torch in the room hinders us from sleeping. For the same reason day succeeding to night awakens us.

* See the Chapter on Motion, Art. CLXII.

troul of the will: it is enough to will it strongly, and we can awake at any hour we choose.

CLXI. *Of dreams and somnambulism.*—Although sleep implies the perfect repose of the organs of sensation and of motion, some of these organs persist in their activity;* which obliges us to acknowledge intermediate states between sleep and waking, real mixed situations, which belong, more or less, to one or to the other. Let us suppose, for instance, that the imagination reproduces in the brain sensations it has formerly known; the intellect works, associates and combines ideas, often discordant, and sometimes natural; brings forth monsters, horrible, or fantastic, or ridiculous; raises joy, hope, grief, surprise, or terror; and all these fancies, all these emotions, are recollected more or less distinctly when we are again awake, so as to allow no doubt but that the brain has been really in action during the repose of the organs of sense and motion. *Dreams* is the name given to these phenomena.† Sometimes we speak in sleep, and this brings us a little nearer to the state of waking, since, to the action of the brain, is added that of the organs of speech. Finally, all the relative functions are capable of action, excepting the outward senses. The brain acts, and determines the action of the organs of motion or speech, only in consequence of former impressions; and this state, which differs from waking only by the inaction of the senses, is called *somnambulism.*

On this head we meet with surprising relations. Somnambulists have been seen to get up, dress, go out of the house, opening and shutting carefully all the doors, dig, draw water, hold rational and connected discourse, go to bed again, and awake without any recollection of what they had said and done in their sleep. This state is always very perilous: for as they proceed entirely upon former impressions, somnambulists have no warning from their senses of the dangers they are near. Accordingly, they are often seen throwing themselves out of a window, or falling from roofs on which they have got up, without being on that account more dexterous in balancing themselves there, as the vulgar believe, in their fondness for the marvellous.

Sometimes one organ of sense remains open to impression, and then you can direct at pleasure the intellectual action. Thus, you will make him that talks in his sleep, speak on what subject you choose, and steal from him the confession of his most secret thoughts. This fact may be cited in proof of the errors of the senses, and of the need there is to correct them by one another.

The condition of the organs influences the subject of the dreams. The superabundance of the seminal fluid provokes libidinous dreams; those labouring under pituitary cachexies will dream of objects of a hue like that of their humours. The hydropic dreams of waters and fountains; whilst he who is suffering with an inflammatory affection, sees all things tinged red, that is, of the colour of blood, the predominant humour.

Difficult digestion disturbs sleep. If the stomach, over-filled with food, hinders the falling of the diaphragm, the chest dilates with difficulty, the blood, which cannot flow through the lungs, stagnates in the right cavities of the heart, and a painful sensation comes on, as if an enormous weight lay upon the chest, and were on the point of producing suffocation: we awake with a start, to escape from such urgent danger: this is what we call night-

* The individual who even enjoys the most profound sleep, seldom wakens in the same position as that in which he was at the moment of falling asleep: it is changed frequently during the time, owing, perhaps, to certain obscure sensations giving rise to movements analogous to those of the fœtus in utero, although more perfect, and seemingly influenced by habit, &c.

† See the Note on *Dreaming*, in the APPENDIX, Notes H H.

mare, an affection that may arise from other causes, hydrothorax, for instance, but which always depends on the difficult passage of blood through the lungs.

The intellectual faculties which act in dreams, may lead us to certain orders of ideas which we have not been able to compass while awake.

Thus mathematicians have accomplished in sleep the most complex calculations, and resolved the most difficult problems. It is easily understood how, in the sleep of the outward senses, the sensitive centre must be given up altogether to the combination of ideas in which it must work with more energy. It is seldom that the action of imagination on the genital organs, during waking, goes the length of producing emission: nothing is more common in sleep.

The human species is not the only one that in sleep is subject to agitations, which are generally comprehended under the name of dreams: they occur in animals, and most in those whose nature is most irritable and sensible. Thus the dog and horse dream more than the ruminating kinds, the one barks, the other neighs in sleep. Cows that are suckling their calves, utter faint lowings: bulls and rams seem goaded by desires, which they express especially by peculiar motions of their lips.

After what has been said of sleep and dreams, it will not be difficult to explain why there is so little refreshment of the powers from sleep that is harassed by uneasy dreams. We often awake exceedingly fatigued with the distress of imaginary dangers, and the efforts we have made to escape them.

We have seen the relations of man with the external world established by means of peculiar organs, which, through the intervention of nerves, all centre in one, the chief and essential seat of the function of which this chapter treats. As the phenomena of the sensations are brought about by the intervention of an unknown agent, and as, like those of electricity and magnetism, they appear not to be subject to the ordinary laws of matter and motion, they have thrown open the widest field to the conjectures of ignorance and the inventions of quackery. It is for their explanation that the greatest abundance and the wildest of theories have been devised.*

* Take, for instance, the following:—On the 23d of December, it is not said in what year, a physician of Lyons, M. Petetin, was called in to a young lady of nineteen, sanguine and robust. She was cataleptic. The doctor employed various remedies; and, among others, one day bethought himself of pushing over the patient on her pillow: *he himself fell with her*, half stooping upon the bed, and this led him to the "discovery of the transport of the senses in the epigastrium to the extremity of the fingers and of the toes." I use his own pompous and barbarous expressions in announcing his discovery. Our doctor goes on to tell, with all gravity, how, putting a bun on the epigastrium of the patient, she perceived the taste, which was followed by motions of deglutition. If his word is to be taken, hearing, smell, taste, sight, and touch, were all there; the outward senses being for the time completely laid asleep. To give an air of credibility to the matter, he adds, that she saw the inside of her body, guessed what was in the pockets of bystanders, and made no mistake in the money in their purses; but the miracle was over the moment they lapped the objects in silk, or a coat of wax, or interposed any other non-conductor. Finally, to put to proof the whole power of faith in his readers, M. Petetin exclaims, "Oh, prodigy beyond conception! was a thought formed in the brain, without any sign of it in words, the patient was instantly acquainted with it."† Further details of so incredible a story would be altogether superfluous.

I should not have disturbed the book of M. Petetin from its peaceful slumber among the innumerable pamphlets which Mesmerism has brought into the world, if a writer on physiology had not been the dupe of this mystification, and had not proceeded, from it, to write a long chapter on metastases of sensibility.

If we should be so unfortunate as to be reproached by the lovers of the marvellous with pushing scepticism too far, we must make answer, that M. Petetin is the sole witness of his miracle; that it is impossible, from his relation, to know when or on whom the prodigy took place; and that this zealot of magnetism might have invented this story to confound the unbelievers who ventured to turn into ridicule his system on the electricity of the human body.

† *Electricité Animale* 1 vol. 8vo. *Lyon*, 1808.

CHAPTER VIII.

OF VOLUNTARY MOTION.

CLXII. Division of Motion into active and passive.—CLXIII. Of the Structure and Properties of Muscles and Tendons.—CLXIV. Of the Phenomena of Muscular Contraction.—CLXV. Theory of Muscular Contraction.—CLXVI. Of the Preponderance of the Flexor Muscles over the Extensors.—CLXVII. Pathological Physiology of Muscular Action.—CLXVIII. Of the Power of the Muscles, and of the mode of estimating that Power.—CLXIX. Of the fixed Point, or Fulcrum, in Muscular Actions.—CLXX. Of the Nature of Muscular Flesh.—CLXXI. and CLXXII. Of Galvanism.—CLXXIII. Apparatus of Volta.—CLXXIV. Relations and Medical Uses of Galvanism.—CLXXV. General View of the Osseous System.—CLXXVI. Structure of the Bones.—CLXXVII. Of the Uses of the Periosteum and of the Medullary Juices.—CLXXVIII. Of the Articulations, the Articulating Cartilages, the Ligaments, and the Synovial Fluid.—CLXXIX. Theory of Anchylosis.—CLXXX. Of Standing, &c.—CLXXXI. to CLXXXV. Of the Mechanism of Standing.—CLXXXVI. Of the recumbent Postures.—CLXXXVII. Of the Motions of Progression.—CLXXXVIII. Of Running.—CLXXXIX. Of Leaping.—CXC. Of Swimming.—CXCI. Of Flying.—CXCII. Of Crawling.—CXCIII. Of partial Motions performed by the upper Extremities.

CLXII. *Division of motions into active and passive.*—This chapter will treat only of the motions performed by the muscles under the influence of the will: they are called muscles of locomotion, as it is by means of them that the body changes its situation, moves from one spot to another, avoids or seeks surrounding objects, draws them towards itself, grasps them, or repels them. The *internal*, *involuntary*, and *organic* motions, by means of which each function is performed, have already been investigated separately.

The organs of motion may be distinguished into *active* and *passive;* the former are the muscles, the latter the bones, and all the parts by which they are articulated. In fact, when in consequence of an impression received by the organs of sense, we wish to approach towards the object that produced it, or to withdraw from it, the muscular organs, called into action by the brain, contract; while the bones, which obey this action, perform only a secondary part, are passive, and may be looked upon as levers absolutely inert.

CLXIII. *Of the structure and properties of the muscles and tendons.*—The muscles consist of bundles of fibres, always, to a certain degree, red in man: this colour, however, is not essential to them, since it may be removed, and the muscular tissue blanched by maceration or by repeated washing.

Whatever may be the situation, the length, the breadth, the thickness, the form, or the direction of a muscle, it is formed of a collection of several fasciculi of fibres, enveloped in a cellular sheath, similar to that which covers the muscle itself and separates it from the surrounding parts. Each fasciculus is formed of the union of a multitude of fibres, so delicate that anatomy cannot reduce them to their ultimate division, and that the smallest distinguishable fibre is still formed by the juxta-position of numerous fibrillæ of incalculable minuteness. As the last divisions of the muscular fibre completely elude our means of investigation, it would be very absurd to attempt to explain their minute structure, and, after the example of Muys, to write a voluminous work on this obscure part of physiology. Shall we say, with the above author, that each distinguishable fibre is composed of three fibrillæ, progressively decreasing in size; with Leuwenhoek, that the diameter of this elementary fibre is only the hundred thousandth part of a grain of sand; with Swammerdam, de Heyde, Cowper, Ruysch, and Borelli, that this primitive fibre consists of a series of globular, rhomboidal molecules; with Lecat, that it is nervous; with Vieussens and Willis, that it is formed by the ex-

treme ramifications of arteries; with others, that it is cellular, tomentose, &c.? How is it possible to speak, with any degree of certainty, of the nature of the parts of a whole, which, from its extreme minuteness, eludes our most accurate investigations? To explain the phenomena of muscular action, it is sufficient to conceive each fibre as formed of a series of molecules of a peculiar nature, united together by some unknown medium, whether that be oil, gluten, or any other substance, but whose cohesion is manifestly kept up by the vital power, since the muscles yield, after death, to efforts by which during life they would not have been torn; and such is their tenacity, that they are very seldom ruptured.*

These fibres, which, when irritated, possess in the highest degree the power of shortening themselves—of contracting, however minute one may suppose them, are supplied with vessels and nerves. In fact, though they are neither vascular nor nervous, as may be readily ascertained by comparing the bulk of the vessels and nerves which enter into the structure of the muscles with that of these organs, and by attending to the difference of their properties,—each fibre receives the power of contracting from the blood brought to it by the arteries, and from the fluid transmitted from the brain along the nerves. A cellular sheath surrounds these fibrillæ (and the nerves and vessels, perhaps, terminate within it);† others unite them together: the fasciculi of fibres are enclosed in common sheaths, and these unite in the same manner into masses varying in size, and the union of which forms the muscles. Fat seldom accumulates in the cellular tissue which connects together the smallest fasciculi; it collects in small quantity in the interstices of the more considerable fasciculi. Lastly, it is in rather greater quantity around the muscle itself. A lymphatic and aqueous vapour fills these cells,

* M. Bauer, by the assistance of his powerful microscope, discovered muscular fibres to be chains of globules, and he conceived that they may be constructed from the globules of fibrine arranged in lines.—*J. C.*

† The majority of anatomists suppose that the muscular fibre itself is beyond the circuit of the circulation; and this appears in some points of view the correct opinion, if we attend to the form and size of the fibres, and to their connexions with the cellular tissue; but, although we may grant that the red globules of the blood do not circulate through the muscular fibres themselves, and that these globules pervade only the capillaries of the connecting cellular substance, still we must allow that they are formed, and afterwards supported, either by the vessels conveying red blood, assimilation taking place in the manner of a deposit from them, without any continuity of texture, or by the medium of a direct communication and admixture of a particular series of capillary terminations of vessels with the muscular fibre, into which the red globules cannot enter, owing to the great tenuity of these capillaries. If we choose the former alternative, which appears, however, the least probable, we may conceive that the nervous terminations in muscular parts soften into an invisible pulp, and unite intimately with the capillary vessels, and with the cellular texture which connects the individual muscular fibres; and that the chain of globules, of which these fibres are composed, being acted on by the influence resulting from the action of the nervous on the vascular terminations, in the enveloping cellular substance, experience in consequence a contraction in proportion to the nervous excitement. In this case we must suppose a certain influence to emanate from the connecting medium to the muscular fibre, without any other communication than that of contact or contiguity. If, on the other hand, we adopt the latter alternative, and believe that an order of capillary vessels, of great tenuity, enters into the structure of muscular fibres, and that the voluntary and organic nerves which blend with the capillary vessels also proceed to and terminate in this structure, we may farther conclude—and, indeed, the conclusion will necessarily follow—that the muscular fibre is composed of a certain order of capillary vessels, and of the terminations of the ganglial nerves (which nerves we must suppose to supply, and to terminate with these capillaries, as they are found to envelope, and to be distributed to the muscular and internal coats of the larger ramifications or trunks of the vessels whence the capillaries are sent off,) with the extremities of the voluntary nerves, which are so abundantly supplied to the muscles of locomotion. Having considered that the muscular fibre is formed from this combination, we have not data whence we can farther infer its intimate nature, or the extent to which each of these systems contributes to its formation in the voluntary muscles. We may suppose, however, that the functions of these textures differ according as either of the constituents which we have now assigned them predominate in their constitution, (see note at p. 12). The observations of M. Bauer, we may state, seem to support the view we have now offered.—See APPENDIX, Notes I I, for farther observations on this subject, and on *Irritability*. —*J. C.*

maintains the suppleness of the tissue, and promotes the action of the organ, which a fluid of more consistence would have impeded.

The greater number of muscles terminate in bodies, generally round, of a brilliant white colour, that forms a striking contrast with the red colour of the muscular flesh, into which one of their extremities is imbedded, while the other extremity is attached to the bone, and is lost in the periosteum, though the tendons are quite distinct from it. The tendons are formed by a collection of longitudinal and parallel fibres: their structure is more compact than that of the muscles; they are harder, and apparently receive neither nerves nor vessels; they consequently possess but a very inferior degree of vitality; hence they are frequently ruptured by the action of the muscles. The muscular fibres are implanted on the surface of the tendinous cords, without being continuous with the filaments forming the latter: they join them in a different manner, and at angles more or less obtuse.

The tendons, in penetrating into the fleshy part of the muscles, expand, become thinner, and form thus the internal aponeuroses. The external aponeuroses, independent of the tendons, though the same in structure, differ from them only in the thinness and greater surface of the planes formed by their fibres. At one time they cover a portion of the muscle to which they belong; at another, they surround the whole limb, furnishing points of insertion to the muscles: they prevent the muscles and their tendinous cords from being displaced; and in a manner direct their action and increase their power, in the same way as a moderately tight girdle adds to the power of an athlete.

We cannot admit, with Pouteau, that the muscles of the limbs, though applied to the bones by aponeurotic coverings, can become displaced, so as to form herniæ. When they contract in a wrong position, some fibrillæ are torn, and this gives rise to most of those momentary and very sharp pains called cramp. I have at present before me the case of a young girl, in whom the aponeurosis of the leg, exposed in consequence of an extensive ulceration, exfoliated from the middle and fore part of the limb to the instep. This exfoliation was accompanied by a displacement of the tibialis anticus, and of the extensors of the toes; the leg is become deformed, the motions of extension of the foot and toes are performed with difficulty, and will soon become impossible, when the exfoliation of the tendons follows that of the aponeurosis which protected them from the air.

CLXIV. *Phenomena of muscular contraction.*—When a muscle contracts, its fibres are corrugated transversely, its extremities are brought nearer to each other, then recede, and again approach towards one another. These undulatory oscillations, which are very rapid, are followed by a slighter degree of agitation; the body of the muscle, swollen and hardened in its decurtation, has acted on the tendon in which it terminates; and the bone to which the latter is connected is set in motion, unless other agents, more powerful than the muscle which is in action, prevent its yielding to that impulse. Such are the phenomena exhibited by the muscles exposed in a living animal or in man, when their contractions are brought on by the application of a stimulus. But these contractions, determined by external causes, are never so strong or instantaneous as those which are determined by the will in a powerful and sudden manner. When an athletic man, reduced by illness, powerfully contracts the biceps muscle of the arm, this muscle is seen to swell suddenly, to stiffen, and to continue motionless in that state of contraction, as long as the cerebral influence, or the act of the will, which determines it, lasts.

Though the muscles manifestly swell in contracting, and though the

limbs are confined by the ligatures applied round them, the whole bulk of the contractile organ diminishes ; it loses in length more than it gains in thickness. This is proved by Glisson's experiment, which consists in immersing the arm in a vessel filled with a fluid, which sinks when the muscles act. We cannot, however, estimate the diminution of bulk by the degree in which the fluid sinks, since that effect is in part owing to the collapse of the layers of the adipose tissue, which is compressed in the muscular interstices.

A sound state of the vessels and nerves distributed to muscles is indispensable to their contraction. If the free circulation of the blood or of the nervous fluid, is prevented by tying the arteries or nerves ;—if the return of the blood along the veins is prevented by applying a ligature to these vessels–the muscles will be completely palsied. By dividing or tying the nerves, the action of the muscles to which they are distributed is suddenly interrupted. The same effect may be produced by intercepting the course of the arterial blood, though in a less rapid and instantaneous manner ; and it is very remarkable, that it is equally necessary that the veins should be as sound as the arteries to enable muscular action to take place. Kaaw Boerhaave ascertained, by actual experiment, that when a ligature is applied to the vena cava, above the iliacs, paralysis of the lower extremities is brought on, as readily as when the aorta is tied, as was done by Steno in the same situation.* And this is a further proof of what we have said elsewhere, of the stupefying qualities of the blood which flows in the veins.

The irritability of the muscles destined to voluntary motions is proportioned to the size and number of the nerves and arteries which are distributed to their tissue.† The tongue, which of all the contractile organs receives the greater number of cerebral nerves, is likewise that which, of all those under the controul of the will, has most extent, most freedom, and the greatest variety of motions.‡ The muscles of the larynx and the intercostals receive nearly as many, considering the smallness of these parts.||

CLXV. *Theory of muscular contraction.*—Of all the hypotheses applied to the explanation of the phenomena of muscular contraction, that appears to me the most ingenious and the most probable which makes it to depend on the combinations of hydrogen, of carbon, of azote, and other combustible substances in the fleshy part of the muscle, with the oxygen conveyed with the blood by the arteries.

To effect this combination it is necessary, not only that the muscle be supplied with arterial blood, and that oxygen come in contact with the substances which it is to oxydise, but it is required that a stream of nervous fluid

* Ligature of the aorta may be conceived to produce paralysis, owing chiefly to the stop it puts to the circulation of arterial blood in that part of the spinal cord, and in the neurilema of the nerves, below where the ligature is placed.

† See APPENDIX, Notes I I.

‡ It is scarcely necessary to repeat, that I am not speaking of those motions, more or less involuntary, performed by muscles which receive the nerves, in part or wholly, from the great sympathetics. Though the particular nature of these nerves has a remarkable influence on the organs to which they are distributed, we find that the general rule is almost without exceptions, for the heart and diaphragm, which hold the first rank among the parts endowed with irritability, receive a considerable number of vessels and nerves.

|| The disposition of the muscles to contract is different from, and even opposite to, their energy of contraction. The feeble muscles of an hysterical female contract so readily and so frequently from the slightest irritation, as nearly to appear involuntary in their actions ; while, on the contrary, the powerful muscles of the athlete act only from energetic stimuli and from fully expressed volition. Thus we observe in feeble individuals a certain mobility of muscular parts and organs which does not exist in the robust, as if the irritability of such parts was excited with a facility in proportion to the deficiency of energetic action. The disposition of muscles to contract differs also according to the age of the animal, and it bears even some relation to the organisation of the muscle itself.

See APPENDIX, Notes F F, for remarks on the period at which the voluntary muscles are formed, and on their appearances and constitution at the different periods of life.—*J. C.*

should penetrate through the tissue of the muscle, and determine the decompositions which take place, as the electrical spark gives rise to the formation of water by the combination of the two gases of which it consists. According to this theory, first proposed by Girtanner, all the changes which take place during the contraction of a muscle,—the turgescence, the decurtation, and the induration of its tissue, and its change of temperature, depend on this reciprocal action of the elements of the muscular fibre, and of the oxygen of arterial blood.

Muscular flesh is harder, firmer, and more oxydised, according as the animal takes much exercise. We well know what a difference there is between the flesh of wild and of the domestic animals; between the flesh of our common fowl and that of birds accustomed to remain long on the wing: in the former it is white, tender, and delicate; while in the latter, it is tough, stringy, dark-coloured, carbonaceous, and of a very strong smell. Respiration, of which the principal use is to impregnate arterial blood* with the oxygen necessary to the contractions of the muscular fibre, is more complete, and decomposes the greater quantity of atmospherical air in those animals that are naturally destined to most exertion. Those birds which support themselves in the air by powerful and frequent motions, have likewise the most active respiration. Athletes, who astonish us by the developement of their muscular organs, and by the powerful efforts of which they are capable, all have a very ample chest, a powerful voice, and very capacious lungs.† In running, as there is a considerable consumption of the principle of motion, we pant, that is, we breathe in a hurried manner, that there may be the greatest possible quantity of blood oxydised to perform the contractions necessary to the exercise of running.

The recent experiments of MM. Prevost and Dumas shew, that at the moment when the influx of nervous influence occasions muscular contraction, each muscular fibre is thrown into a zig-zag form. At each point of flexion is placed a nervous filament, the direction of which is perpendicular to that of the muscular fibres. But the nervous filament does not terminate there, nor unite with the muscular fibre, but merely embraces it by a loop; for, after having crossed the muscular fibre nearly at a right angle, the nervous filament is reflected upon itself, and rejoins the branch whence it proceeded. Such being the conformation, the phenomenon of muscular contraction takes place by the influence of a double electric current proceeding in opposite directions, and of which the nerves are the conductors. Owing to this double current, and its alternating attractions and repulsions, all the muscular fibres are thrown into a zig-zag form, and are shortened without any augmentation of their bulk.‡

CLXVI. *Of the preponderance of the flexors over the extensors.*§—The extensor muscles are generally weaker than the flexors; hence the most natural position,—that in which all the powers are naturally in equilibrio, that which our limbs assume during sleep, when the will ceases to determine the vital influx to the parts under its control, that in which we can continue longest without fatigue,—is a medium between flexion and extension, a real state of semi-flexion.

* See Appendix, Note W.

† I never saw a very strong man that had not broad shoulders, which indicates a considerable developement of the cavity of respiration. If there be individuals that seem to be exceptions to this general law, it is that by frequent exercise, and by a laborious life, they have increased the natural power of their muscles. This increase is seldom universal, but almost always limited to certain parts which have been most employed, as the arms, the legs, or the shoulders.

‡ See farther remarks on this subject in the Appendix, Notes I I.

§ The theory of the preponderance of the flexors is entirely my own, and was first proposed by me in the collection of Memoirs of the Medical Society of Paris, for the year 1799.

Attempts have been made to discover the cause of this preponderance of the flexor muscles over their antagonists. According to Borelli, the flexors being shorter than the extensors of the same articulation, and contracting equally,* the former must occasion a more extensive motion of the limbs, and determine them towards a state of flexion. But it is, in the first place, incorrect to say that the flexors are shorter than the extensors; and in the next place, if we are to estimate by the length of a muscle the extent of motion that may be produced by its action, we ought not to measure the whole of the fleshy part, nor to include in the calculation the tendinous cord which terminates it, but to consider the length of its fibres, on which depends entirely the extent of motion produced by its contractions.

The degree of decurtation of which a muscle is capable, is always proportioned to the length of its fleshy fibres, as is the power of contraction to the number of the fibres. Now, if the fibres of the flexors are in greater number than those of the extensors, it follows, as a necessary consequence, that the limbs will be brought into a state of flexion when the principle of motion shall be distributed to them in an equal quantity; and even though the number of fibres should be the same in the flexors and extensors, the limbs would still be in a state of flexion, if the fibres of the former being longer, they made the parts move through a greater space.

If we examine the different parts of the body, the articulations of the limbs, and especially of the knee, the knowledge of which is of the highest importance in comprehending the theory of standing, it will be seen that the flexor muscles exceed the extensors in the number and length of their fleshy fibres. If we compare the biceps cruris, the semi-tendinosus, the semi-membranosus, the rectus internus, the sartorius, the gemelli, the plantaris, and the popliteus, which all concur in the flexion of the leg, to the triceps cruris and to the rectus, which extend the leg, we shall readily understand that the fibres of these last are much shorter, and in smaller number. Those of the sartorius and rectus internus are the longest of all the muscles employed in voluntary motion: the fibres of the posterior muscles of the limb are not inferior in length to the fibres of the muscles at the fore part.

Besides, the flexor muscles are inserted into the bones which they are to move, farther from their centre of motion. In fact, if the insertion of the semi-membranosus is situated nearly at the same height, the sartorius, the rectus internus, the semi-tendinosus, the biceps, and the popliteus, are inserted lower than the extensors of the leg. But this difference is particularly observable in the plantaris and gemelli, which terminate at the greatest possible distance from the centre of motion, and which act with a very long lever.† Lastly, most of these muscles depart, much more than the extensors, from a parallel direction to the bones of the leg. We all know the curved line of the course of the sartorius, of the rectus internus, and semi-tendinosus, by which the angle of their insertion becomes more favourable.

The flexor muscles which, on their being first called into action, are nearly parallel to the levers which they are to move, tend to become perpendicular to them in proportion as the motion of flexion is carried on. Thus, the brachialis, the biceps brachii, and the supinator longus, the mean line of direction of which is nearly parallel to that of the bones of the fore-arm, when the flexion of this limb commences, become oblique, then perpendicular to

* "Musculi flexores ejusdem articuli breviores sunt extensoribus, et utrique æque contrahuntur." *Prop.* 130, *de motu animalium.*

† We may, in this respect, compare the gemelli to the supinator longus, the use of which is not limited, as was shewn by Heister, to the supination of the hand, but which is likewise a flexor of the fore-arm, and acts the more powerfully as its inferior insertion is at a greater distance from the elbow joint, and as its fibres are the longest of all those of the muscles of the upper extremity.

this bone, and at last form with it the angle most favourable to their action. The same applies to the flexors of the leg: the angle of their insertion becomes greater the more it bends on the thigh. The extensors, on the contrary, are in the most favourable state for action at the moment when their contraction begins: in proportion as the extension goes on, they have a tendency to become parallel to the levers which they set in motion, and their action even ceases before the parallelism is complete, at the elbow by the resistance of the olecranon, and at the knee by the numerous ligaments and by the tendons situated towards the posterior part of the articulation.

The flexor muscles have, therefore, fibres of greater length, and more numerous, than those of the extensors. They are inserted into the bones at a greater distance from the centre of their motion, at an angle less acute, and which increases in size as the limbs bend. The union of these causes gives to the limbs their superior power; and the greater range of motion in these muscles is a consequence of the arrangement of the articulating surfaces, which almost all incline towards the side of flexion.

This preponderance of the flexor muscles varies according to the different periods of life: in the fœtus, the parts are all bent very considerably. This convolution of the young animal may be perceived from the earliest period of gestation, when the embryo, of the size of a French bean, and suspended by the umbilical cord, floats in the midst of the liquor amnii, in a cavity of which it is more and more confined as it approaches to the period of its birth. This excessive flexion of the parts, which was required to enable the produce of conception to accommodate itself to the elliptical shape of the uterus, concurs in giving to the muscles producing it the superiority which they retain during the remainder of life.

The new-born child preserves, in a very remarkable manner, the habits of gestation; but, in proportion as it grows, it straightens its body, and, by frequent attempts to stretch itself, shews that a just proportion is about to take place between the muscular powers. When the child becomes capable of standing erect, abandoned to its own powers, all its parts are in a state of semi-flexion,—it staggers, and is unsteady on its feet. Towards the middle of life the preponderance of the flexors over the extensors becomes less apparent—a man enjoys fully and completely his power of locomotion; but, as he advances in years, this power forsakes him; the extensor muscles gradually return to the state of comparative debility of infancy, and become incapable of supporting the body in a fixed and permanent manner.

CLXVII. *Pathological physiology of muscular action.*—The state of our limbs during sleep approaches to that of the fœtus, which, according to Buffon, may be considered to be in a profound slumber. The cessation of sleep is attended in man, as well as in most animals, by frequent stretchings. We extend our limbs forcibly, to give to the extensors the tone which they require during the state of waking.* Barthez accounts in the same way for the manner in which the cock announces his waking, by crowing and flapping his wings.

It may happen, in consequence of a morbid determination of the vital principle, that our limbs may remain in a state of extension during sleep. Hence Hippocrates recommends that the state of the limbs be carefully attended to while the patient sleeps; for, as he observes, the farther that condition is from the natural state, the greater the danger to be apprehended

* Haller thinks that these extensions are intended to relieve the uneasy sensations occasioned by a long-continued flexion. "*Nunc quidem homines et animalia extendunt artus, quod iis ferè conflexis dormiant, et ex eo perpetuo situ, in musculis sensus incommodus oriatur, quem extensione tollunt.*" (*Phænomena expergiscentium, Elementa Physiologiæ*, tom. v. p. 621).

of the patient's life. In certain nervous diseases, characterised by a manifest aberration in the distribution of the vital power, a continued state of extension must be considered a symptom highly dangerous. I have had several times occasion to observe, that in cases of wounds attended with convulsions and tetanus, these alarming affections were announced by the permanent extension of the limbs during sleep, before a difficulty of moving the jaw could give rise to any apprehension of their approach.

Disease, and excesses of all kinds, occasion in the extensor muscles a relative weakness that is very remarkable: hence we see convalescents, and those who have been addicted to voluptuousness, walk with bending knees; the more so as their debility is greater, and as the force of the extensors is more completely exhausted. The flexion of the knees is then limited by that condition in which the tendons of the extensors of the leg act on the tibia, at an angle sufficiently great to make up for their diminished energy. There exists a condition of the animal economy in which all the muscular organs appear wearied with exertion, and the limbs assume indifferently any position. In this state, which is always a very serious one, as it indicates an almost complete want of action in a system of organs whose functions are absolutely essential to life—a state to which physicians have given the name of *prostration*,* the limbs, if unsupported, fall of their own weight, as if they were palsied, the trunk is motionless and supine, the patient is incapable of changing his attitude, and, yielding to the weight of his body, sinks on the inclined plane formed by the bed, and seems very heavy to those who may attempt to raise him, because, from his helplessness, he requires to be moved as an inert substance.

CLXVIII. *Of the power of the muscles, and of the mode of estimating that power.*—The actual power of the muscles is immensely great, seems to grow in proportion to the resistance which it meets with, and can never be estimated

* It is from a knowledge of the strength of his patient that the physician, in the treatment of disease, deduces the most instructive indications. It seems to me, that we ought to endeavour to characterise by specific terms the different states of animal adynamia in different diseases. Our language, less fruitful in imagery than the ancient languages, will not easily furnish these characteristic denominations, so useful in a science which should paint objects in their truest colours, in terms most approaching to nature. It will, therefore, be necessary to have recourse to the Greek and Latin languages, and perhaps to give the preference to the latter, which is generally understood by those who practise the art of healing. The application of this principle to the different kinds of fever will prove its utility, and will doubtless be an inducement to extend it to all the classes of morbid derangements.

In febre inflammatoriâ seu synocho simplici (angeiotenicâ)	*Oppressio virium.*
In febre biliosâ seu ardente (meningo-gastricâ)	*Fractura virium.*
In febre pituitosâ seu morbo mucoso (adenomeningeâ)	*Languor virium.*
In febre putridâ (adynamicâ)	*Prostratio virium.*
In febribus malignis seu atactis	*Ataxia virium.*
In febre pestilentiali (adeno-nervosâ)	*Sideratio virium.*

The first term, which is easily turned into French, expresses, with much precision, that condition in which the living system, far from being deficient in strength, is encumbered by its excess, and is oppressed by its own powers. It might, with slight modifications, be applied to all the kinds of phlegmasias and active hæmorrhages.

The second denomination, not so easily translated, expresses the sense of general contusion and bruise, of which patients labouring under bilious fever (*meningo-gastrica*) complain all over the limbs.

This sensation is likewise, it is true, experienced in pituitary fever: but this is more particularly characterised by languor and loss of strength. The same is to be observed in many patients of a phlegmatic temperament.

The prostration, which is so remarkable a character of putrid fevers, and in consequence of which they are called adynamic, is easily recognised by the total cessation, or by an impaired condition of all the functions performed by muscular organs, as voluntary motion, respiration, circulation, digestion, the excretion of urine, &c.

The disordered condition of the vital powers characterises the ataxiæ. There is considerable irregularity in these fevers, with a very anomalous course of symptoms. In this point of view, one might compare it to several kinds of nervous disorders.

Lastly, the word syderation appears to me to express very forcibly that sudden and deep stupor which overwhelms patients seized with the plague of the East.

with precision. Borelli was guilty of a serious mistake in estimating the force of a muscle by its weight compared to that of another muscle; for muscles may contain cellular tissue, fat, tendinous parts, and aponeuroses, without being the more powerful. Their strength is always proportioned to their fleshy fibres: hence Nature has multiplied those fibres in the muscles which are intended for powerful action. And in order that this great number of muscular fibres might not add too much to the bulk of the limbs, they are made shorter, by bringing near to each other their insertions, which occupy extensive surfaces, whether aponeurotic or osseous. We may, in general, judge of the power of a muscle by the extent of the surfaces to which its fleshy fibres are attached; thus, the gemelli and the soleus have short compressed fibres, and lying obliquely between two large aponeuroses.

If the force with which a muscle contracts is proportioned to the number of its fibres, the degree of decurtation of which it is capable, and consequently the range of motions which it can communicate to the limbs, are proportioned to the length of the same fibres.* Thus the sartorius, whose fibres are longer than any in the human body, is also capable of most contraction, and performs the most considerable motions of the leg. It is impossible to fix any precise limits to the decurtation of every particular muscular fibre; for, if the greater part of the long muscles of limbs lose little more than a third of their length in contracting, the circular fibres of the stomach, which in its greatest dilatation form circles nearly a foot in diameter, may contract to such a degree, when this organ has been long empty, as to form rings of scarcely an inch in circumference. In cases of extreme elongation or constriction, does the change that takes place affect the molecules that form the muscular fibre, or the substances which connect them together? or does it affect at once both the fibre and the parts by which these fibres are united together?

However great the power of the muscles may be, a great part of this power is lost from the unfavourable disposition of our organs of motion: the muscular powers, almost always parallel to the bones which they are to move, act with the more disadvantage on these levers, as the mean line of their direction is further from the perpendicular, and is nearly parallel to them.

The greater part of the muscles are, besides, inserted in the bones very near their articulations, or the centre of motion, and move them as levers of the third kind, that is, are always placed between the fulcrum and the resistance: by multiplying thus, in the animal machine, the levers of the third kind, Nature has lost in power, but has gained in strength, for in this kind of lever the power moves through a very small space, but makes the resistance move through a very considerable one. Moreover, the fleshy fibres, in shortening themselves, do not act directly on the tendon in which the muscle terminates: these fibres generally join, in an oblique direction, the aponeurotic expansion formed by the tendinous cord, as it penetrates into the muscular mass. Now their action being exerted in a direction more or less oblique, is decomposed, and none is advantageously employed but that which takes place in the direction of the tendon. The muscles frequently pass over several articulations in their way to the bone which they are to move; and hence a part of their power is lost, in the different degrees of motion on each other, of the parts on which the bone into which the muscles are inserted rests. All these organic imperfections are attended with an enormous misapplication

* Besides these data, we should take into consideration the energy of the nervous impulse under which voluntary muscles contract. We perceive nearly as great differences in the activity, the intensity, the frequency, and in the continuance of muscular contraction, result from the state of the nervous system, even in health, as may be imputed to the form and size of the muscles themselves, unless the difference of their constitution or size be very considerable. —*J. C.*

of power, and with a waste of the greater part of it. It has been reckoned that the deltoid muscle employs a power equal to 2568 pounds to overcome a resistance of 50. We are not to imagine, however, that there is a loss of 2518 pounds; for the deltoid muscle acting both on the shoulder and on the arm, about one-half of its power is employed on each of these parts; hence it is said, that in estimating the whole power of a muscle, one should double the effect produced by its contraction, its action being employed at the same time both on the weight which it raises, or on the resistance which it overcomes, and on the fixed point to which its other extremity is inserted.

If the muscles were quite parallel to the bones, they would be incapable of moving them in any direction. On this account Nature has, as much as possible, corrected the parallelism by removing, as we shall see in speaking of the osseous system, the tendons from the middle line of direction of the bones, and by augmenting the angles at which they are inserted into them, either by placing along their course bones which alter their direction, as the patella and the sesamoid bones, by increasing the size of the articular extremities of the bones, or by pullies, over which the tendons or the muscles themselves are reflected, more or less completely, as in the case with the circumflexus palati and the obturator internus.

Nature has not, therefore, neglected mechanical advantages as much as one might be led to imagine on a slight examination of the organs of motion. And if it be considered, that in the different conditions of life we do not require strength so much as rapidity of motion, that the power might be gained by increasing the number of fibres, while it was impossible to obtain velocity by any other means than by employing a particular kind of lever, and that, in short, to give our limbs the most advantageous form, it was necessary that the muscles should be applied to the bones,—it will be confessed, that in the arrangement of these organs, Nature, in frequently sacrificing power to quickness of motion, has conciliated, as much as possible, these two almost irreconcileable elements.

Though the lever of the third kind is that most frequently employed in the animal economy, the two other kinds of lever are not altogether excluded from it: there are even limbs which represent different levers, according to the muscles which set them in motion; thus, if we take the foot as an instance, it will present us with levers of every kind. The foot, when raised from the ground, and held up, and directed in the axis of the leg, forms a lever of the first kind; the fulcrum is in the articulation, and separates the power, which is at the heel, from the resistance, which is at the tip of the foot that points downwards: if this end of the foot rest on the ground, and if we stand on tip-toe, they are changed into levers of the second kind; the power continues at the heel, but the fulcrum is removed to the other extremity of the lever, and the resistance to the middle; and this resistance is very considerable, since the whole weight of the body rests on the articulation of the foot with the leg. In standing on tip-toe, the muscles of the calf of the leg become prodigiously fatigued, though their action is assisted by the most favourable lever,* adapted to the greatest resistance which Nature can oppose to herself. Lastly, the foot moves as a lever of the third kind when we bend it on the leg.

CLXIX. *Of the fixed point, or fulcrum, in muscular action.*—What is called the fixed point, in the action of muscular organs, does not always deserve that name. Thus, though it may be said very correctly, that the greater part of the muscles of the thigh have their fixed point in the bones of the

* Of levers with arms of unequal length, that of the second kind is the most favourable, since the arm of the power is uniformly longer than that of the resistance.

pelvis, to which their upper extremity is attached, and though they move the femur on the ilia, which are less movable, when the thigh is fixed by the action of other muscles, these move the pelvis on the thigh, and that which was the fixed point becomes movable. The same applies to the other muscles of the body, so that the fixed point is merely that which generally is a fulcrum to the muscular action. This necessary fixed state of one of the bones, to which is attached one of the extremities of a muscle which we wish to contract, renders it necessary, in performing the slightest motion, that several muscles should be called into action, which implies a very complicated mechanism. Nothing is easier to prove. Suppose a man stretched on the ground, or lying on his back, if he wish to raise his head, it will be necessary that his chest become the fixed point of action of the sterno cleido mastoidei, whose office it is to perform this motion. Now, in order that the pieces forming this osseous structure may remain motionless, it will be required that the chest should be fixed by the action of the abdominal muscles, which, on the other hand, have their fixed point in the pelvis, that is itself fixed in its place by the contraction of the glutæi muscles. It was on this principle that Winslow first suggested, that in reducing a hernia, the patient should be laid in a horizontal posture, with injunctions not to raise his head, that the abdominal muscles being relaxed, their different openings might yield more easily to the reduction of the parts.

In case the two opposite points to which the extremities of a muscle are attached, are equally movable, they approach towards each other during the contraction of the muscle, by making them move through equal spaces. These spaces would not be equal if the mobility were different. Each muscle has its antagonist, that is, another muscle whose action is directly opposed to it. Thus the flexors balance the action of the extensors, the adductors perform motions different from those of the abductors. When two antagonising muscles of equal power act, at the same time, on a part equally movable in every direction, the opposite powers neutralise each other, and the part remains motionless. If there is a difference in the degree of contraction, the part is directed towards the muscle whose contraction is the most powerful; if the opposition is not direct, the part follows a middle direction, between the two powers which move it. Thus the rectus externus muscle of the eye is not antagonised by the rectus inferior: hence when these two muscles come to contract at the same time, the eye is not carried downward or outward, but at once downward and outward; it is then said to move in the diagonal of a parallelogram, of which the sides are represented by the muscles in action.

CLXX. *Of the nature of muscular flesh.*—I shall not speak at present of the manner in which the muscles receive nourishment, by retaining within the meshes of their tissue the fibrina, which the blood conveys to them in such quantity, that several among the ancients and moderns have called the blood, "liquid flesh;" an expression at once forcible and correct, since all the organs are repaired and grow by the solidification of its different parts. Haller first observed that most of the muscular arteries were very tortuous in their course to the muscles. This disposition, which cannot fail to slacken very considerably the course of the blood, favours the formation and the secretion of the fibrous element which the muscles appropriate to their own substance, and to which it bears so strong an affinity. Motion influences, in a very remarkable manner, this nutritive secretion. The muscles that are most in action uniformly acquire the greatest size and strength; if left in a state of complete inaction, they become exceedingly reduced in size, from the suspended secretion of the fibrinous principle. Muscular motion pro-

motes very remarkably the circulation and the distribution of all the fluids. The flow of venous blood, after bleeding, is never copious, unless the muscles of the fore-arm are made to contract, by allowing the patient to hold the lancet case, and desiring him to move it round in his hand.

The chemical nature of the muscular fibre is nearly the same as that of the fibrine obtained from the blood.* Like the latter, it contains a great quantity of azote, and is, consequently, very much animalised and exceedingly putrescent. It was from muscular flesh that M. Berthollet obtained, in considerable quantity, the peculiar animal acid, called by that chemist the *zoonic acid.*† Lastly, the element of the blood, fibrine, by means of which the muscular flesh is repaired, is already imbued with vital properties, even while it yet flows in a state of combination with the other parts of the fluid. This fibrine, extracted from the blood and subjected to the galvanic influence, is distinctly seen to quiver and contract under that influence. At what period does this substance acquire the power of contracting ? It is, doubtless, at the moment when it becomes organised, in passing from the liquid to the solid state. What relation does there exist between the organisation of matter and the vital properties with which it is endowed ? This question cannot be answered in the present state of our physiological knowledge.‡

CLXXI. *Of galvanism.*—A professor of anatomy in the university of Bologna, Galvani, was one day making experiments on electricity. In the laboratory, not far from the machine, lay some skinned frogs, of which the limbs were convulsed every time a spark was taken. Galvani, struck with the phenomenon, made it a subject of inquiry, and found that metals, applied to the nerves and to the muscles of these animals, determined quick and strong contractions when they were disposed in a certain manner. He gave the name of *animal electricity* to this set of new phenomena, from the analogy he thought he perceived between its effects and those of electricity. The discovery was made public : many scientific men, chiefly those of Italy, and Volta among others, were eager to make additions to the labours of the inventor. The Medical Society of Edinburgh thought it right to take this point of physiology as the subject of one of its annual prizes, which was adjudged to the work of Professor Crève, of Mentz, in which the term metallic irritation (*irritamentum metallorum*) is substituted for that of animal electricity. This new expression is essentially bad, since it implies that irritation by metals can alone determine the galvanic phenomena, when charcoal, water, and many other substances, produce them as well. The term of animal electricity has been also laid aside, notwithstanding the great analogy between the effects of electricity and those of galvanism, and this last name has been preferred, which, applying equally to the whole of the phenomena, immortalises the name of the first observer.§

* Nothing can prove, in a more complete manner, the essential difference between the fleshy parts of muscles and their tendinous and aponeurotic parts, than the chemical analysis of these organs. The tendons and aponeuroses may be completely resolved into gelatine by long boiling, which, on the contrary, parches the muscular flesh, by exposing the fibrina, in consequence of the melting of the fat of the cellular tissue, and of the albuminous juices in which it is enveloped.—See the chapter at the end of the APPENDIX, on the Chemical Constitution of the Animal Textures and Secretions. —*J. C.*

† Another principle which is obtained abundantly from muscular tissues, and denominated *osmazome* by modern chemists, may be noticed. It appears to be a species of animal extract, of a brown colour, aromatic and very nutritious. It gives soup its savour, and forms a great proportion of the gravy of meat. Although osmazome is an animal product, it is also found on analysis in some species of mushrooms.—*J. C.*

‡ See APPENDIX, Notes I I.

§ Sulzer, in the Memoirs of the Academy of Berlin, and in his "*General Theory of Pleasure,*" a work published in 1757, and inserted, in 1769, in a collection published by Bouillon, under the title of the "*Temple du Bonheur,*" tome iii. p. 124, had mentioned, that two plates of different metals being placed one above and another below the tongue, and inclined towards each other at their extremities, at the moment when they touched each other, he felt a sharp

To produce the galvanic phenomena, it is necessary to establish a communication between two points of a series of nervous and muscular organs. In this way there is formed a circle, of which one arc is composed of the animal parts that are subjected to the experiment; while the other arc is represented by the instruments of excitation, which consist commonly of several pieces, some of them placed under the animal parts, and called supports, and the others by which the communication with these is established, called *communicators*.

To form a complete galvanic circle, take the thigh of a frog stripped of its skin, detach the crural nerve down to the knee, and apply it on a plate of zinc; let the muscles of the leg lie on a plate of silver, then complete the arc of excitation and the galvanic circle, by establishing a communication between the two supports with an iron wire, or copper, tin, or lead; at the moment of touching the two supports with the conductor, a part of the animal arc formed by the muscles of the leg will be convulsed. Although this arrangement of the animal parts, and of the galvanic instruments, is the one most favourable to the production of these phenomena, there is room for varying a good deal the composition of the animal arc and the arc of excitation. Thus, you obtain contractions by placing the two supports under the nerve, and leaving the muscles without the galvanic circle; which proves that the nerves essentially constitute the animal arc. To conclude, the galvanic circle may be entirely animal: for this purpose take a very lively frog, that is to say, one enjoying strong contractility: after insulating the lumbar nerves, present these nerves to the thigh of the frog: at the moment of contact the limb will be convulsed. Professor Aldini was the first author of this experiment, which is really one of the most curious, as it leads more drectly to the explanation of the influence of nerves on muscular organs.

There is no need that the nerves be untouched to allow the contractions to take place; they are observed when the nerves are tied or cut, provided there be simple contiguity between the two ends made by the section. This shews that no rigorous conclusion should be drawn from what happens in galvanic phenomena to what takes place in muscular action, since it is enough that a nerve in man be cut or compressed by a ligature, to take from the muscles to which it is sent the faculty of moving. I have, however, observed that disorganising, by a strong contusion, the nerve which forms the whole or merely a part of the animal arc, interrupts, or at least greatly impedes, the galvanic current.

The epidermis obstructs galvanic action, which always is faint in parts so covered. When it is moist, thin, and delicate, the interruption is not complete, and hence the possibility is inferred of making on oneself the following experiments.

Lay upon the tongue a plate of silver, and a plate of zinc beneath; let their edges touch, and you will feel a sharp taste, with a slight quivering. Apply upon the eyes two pieces of different metals; make them communicate, and you will perceive sparks. Put a piece of silver in your mouth, and a piece of tin into your anus, or copper, or any other metal; connect them

taste, which was frequently accompanied by a peculiar faint light. Cotugno had related, in a journal published at Bologna, in 1786, that a student of medicine, while dissecting a living mouse, was surprised to observe an electric movement of its limbs whenever the scalpel touched one of the nerves. It was not until 1789 that Galvani commenced his experiments. But he cannot be the less considered as the discoverer of this class of phenomena, even supposing that he knew the experiments we have noticed, for their authors drew no conclusion from them; while, on the contrary, Galvani repeated, varied, and multiplied them, and was the first to contend for a species of electricity in the animal economy.

with an iron wire, the long, hollow muscle, which, reaching from the mouth to the anus, forms the base of the digestive canal, feels a considerable shock: this has been carried the length of exciting a gentle purging, accompanied with slight cholic. Humboldt, after detaching the epidermis from the nape of the neck and the back, by two blisters, had metals applied to the parts laid bare, and felt in each sharp prickings, accompanied with a sero-sanguineous excretion, at the moment of communication.

You may construct the arc of excitation with three kinds of metal, or two, or even one, with alloys, amalgams, or other metallic and mineral combinations, with carbonaceous substances,* &c.; and it is observed that metals, which are in general the most powerful exciters, provoke contractions with the greater success the larger surface they present. The metals have more or less power of excitation: thus, it is found that zinc, gold, silver and tin, hold the first rank; then copper, lead, nickel, antimony, &c. without any apparent relation between their different degrees of exciting power and their physical properties, as their weight, malleability, &c.

Galvanic susceptibility is like muscular irritability: it is exhausted by too long exertion, and returns when the parts are left for a time in repose. Dipping the nerves and muscles in alcohol or opiate solutions, weakens, and even will extinguish, this susceptibility, in the same manner, no doubt, as the immoderate use of the same substances benumbs and paralyses the muscular action in the living man. Immersion in oxygenated muriatic acid restores to the exhausted parts the power of being affected by the stimulus. Humboldt has observed that the season of spring, as well as the youth of the frog, was favourable to the production of the phenomena, and that the fore feet of these creatures, with which the male fixes himself on the back of the female, by pressing her sides, are more excitable than the hind feet; whilst in the other sex, it is the hind feet that are the most susceptible. M. Hallé ascertained, by experiments made at the School of Medicine in Paris, that the muscles of animals killed by repeated shocks of an electrical battery, receive an increase of galvanic susceptibility; that this property subsists, without alteration, in animals dead from asphyxia, or killed by immersion in mercury, pure hydrogen gas, carbonated hydrogen, oxygenated muriatic acid, and sulphureous acid gases, by strangulation, or by privation of air in an exhausted receiver; that it is weakened after suffocation by drowning, by sulphuretted hydrogen, azote, and ammoniacal gas; and absolutely destroyed by suffocation in the vapour of charcoal. Spring is the season in which galvanic experiments succeed best: an excess of life seems, at that time, to animate all beings; it is, accordingly, at this epoch that the greater part of them are employed in the reproduction of their kind.

CLXXII.—Galvanic susceptibility disappears in the muscles of warm-blooded animals as the vital warmth goes off. Sometimes even when their life has ended in convulsions, their contractility is gone, though there be still warmth, as if this vital property were exhausted by the convulsions of death. In the cold-blooded, susceptibility is more permanent: long after separation from the body, and even to the moment when putrefaction begins, the thighs of frogs are affected by galvanic excitation; no doubt because in these animals irritability is less intimately connected with respiration, because life is less one,—is more divided among different organs which have less need of action on each other to produce its phenomena.

Contractility is, then, as I have shewn in another work, too fleeting in the human body† to enable us to derive from galvanic experiments on it after

* I employed successfully, in the winter of the year 1800, pieces of ice, both as supports and as communicators.

† It ceases in the fœtus, and in the new-born, or very young infant, almost immediately with life.—*J. C.*

death, any light on the greater or less weakening of this vital property in different diseases. Those authors who have maintained that galvanic susceptibility is sooner extinct on the bodies of those that die of scorbutic affections, than of those that die of inflammatory diseases, have suggested a probable conjecture, which cannot, however, be established on experiment.

Dr. Pfaff, professor in the university of Kiel, who, next to Humboldt, is, of all the scientific men of Germany, he who has attended most successfully to experiments on galvanism, has had the goodness to communicate to me the following facts.

The galvanic chain produces sensible actions, that is to say, contractions, only at the moment in which it is completed, by establishing a communication among its parts. After the communication is made, or during the time that it remains, all appears tranquil; yet the galvanic action is not suspended. In fact, excitability appears singularly increased or diminished in the muscles that have been left long in the galvanic chain, according to the variations of the reciprocal situation of the associated metals. If the silver have been applied to the nerves, and the zinc to the muscles, the irritability of these is increased in proportion to the time they have remained in the chain. By this means you may revivify, in some sort, frogs' thighs, which will afterwards obey an influence that was no longer sufficient to excite them. By allotting the metals differently, applying the zinc to the nerves, and the silver to the muscles, the opposite effect takes place; the muscles, which were introduced into the chain with the liveliest irritability, seem entirely paralysed, if they have remained long in that situation.

This difference depends, very evidently, on the direction of the galvanic fluid determined towards the nerves or towards the muscles, according to the arrangement of the metals. It is of importance to be known for the application of galvanism to the treatment of disease. Where the object is to revive enfeebled irritability, it is better to employ the tranquil and permanent influence of the closed galvanic chain, by distributing the silver and zinc so that the silver shall be nearest to the origin of the nerves, and the zinc upon the muscles of which it is wished to re-excite the torpid or suspended action, than to employ that sudden influence, which in an instant excites, and is gone. Professor Pfaff told me he had treated successfully a hemiplegia, by placing silver within the mouth, and a plate of zinc on the paralysed arm: at the end of twenty-four hours of uninterrupted communication the limb could already exert some slight motions. To diminish, on the other hand, the irritable energy in many spasmodic affections, you must invert the application of the metals; place the zinc as near as possible to the central extremity of the nerves, and the silver on their superficial terminations.

CLXXIII. *Apparatus of Volta, or galvanic pile.*—Curious to ascertain the relation apprehended by several natural philosophers to subsist between electricity and galvanism, M. Volta invented the following apparatus, which is described, as well as the effects it produces, in a memoir presented by him to the Royal Society of London. These effects shew the most striking analogy between the two orders of phenomena, as will be seen by a succinct view of them. Raise a pile by laying, successively, one above another, a plate of zinc, a piece of moistened pasteboard, and a plate of silver; then a second plate of zinc, &c. till the pile is several feet high—for the effects are stronger the higher it is; then touch at once the two extremities of the pile with the same iron wire: at the instant of contact a spark is seen at the extremities of the pile, and often, at the same time, luminous points, at different heights, in places where the zinc and silver touch. Tried by the electrometer of M. Coulomb, the extremity of the pile which answers to the zinc appears

positively electrified; that which is formed by the silver, gives, on the contrary, indications of negative or resinous electricity.

If, after wetting both hands by dipping them in water, or, still better, in a saline solution, you touch the two extremities of the pile, you feel a shock in the joints of the fingers and elbow, followed by an unpleasant pricking.

This effect may be felt by several persons holding hands, as in the Leyden experiment: it is the more sensible, the composition of the chain being in other respects the same, as the chain consists of fewer people, and as they are better insulated.

Notwithstanding this great resemblance of the effects of galvanism to those of electricity, it differs from it essentially in this, that the voltaic pile is constantly electrifying itself spontaneously, that its effects seem increased the more they are excited, and are speedily renewed in greater strength; whilst the Leyden phial, once discharged, requires to be electrified anew. This loses, moreover, by damp, its electrical properties, whilst those of the pile remain the same, though water is running on all sides, and are quenched only by entire immersion in that fluid.

If you introduce into a tube filled with water, and hermetically closed with two corks, the extremities of two wires of the same metal, which at the other extremity are in contact, one with the summit and the other with the base of the galvanic pile, these two ends, when brought within the distance of a few lines, undergo manifest changes at the moment of touching the extremities of the pile. The wire in contact with the extremity which answers to the zinc, becomes covered with bubbles of hydrogen gas; that which touches the extremity formed by the silver, becomes oxydised. If the ends of the wire dipping into the water are brought into contact, all effect ceases: there is no disengaging of bubbles on one side, no oxydisement on the other. The plates of zinc and silver become alike oxydised in the pile, but only on the surfaces which touch the moistened pasteboard, and very little, or not at all, on the opposite surfaces, &c.

Facts so singular could not but awaken the attention of all natural philosophers. Accordingly, there was a great eagerness every where to repeat and verify these first experiments, to vary and to extend them, and to rectify the errors into which their authors might have fallen. Lastly, it has been attempted to explain the manner in which the apparatus acts in the production of hydrogen gas, and in oxydisement.

M. Fourcroy ascribes this phenomenon to the decomposition of water by the galvanic fluid, which abandons the oxigen to the wire that touches the positive extremity of the apparatus, then conducts the other gas, in an invisible manner, to the extremity of the other wire, where it allows it to escape; and this opinion, supported by many experiments, detailed in a memoir presented to the National Institute, is the most probable of all that have hitherto been suggested.*

The galvanic pile has been employed with effect to produce with more energy muscular contraction. If you place in the mouth of an animal fresh killed a conductor, attached to one of the poles or extremities of the pile, and insert into the rectum the conductor connected with the other extremity, you observe contractions so strong that the whole body of the animal quivers and is agitated, the eyes roll in their sockets, the jaws strike against each other, and the tongue is thrust out. The same effects take place after decapitation of the animal. These experiments have been repeated on the bodies of persons executed by the guillotine: by applying to the neck the head that had

* It is unnecessary to refer to the brilliant discoveries which have been made in chemical science by means of galvanism.—*J. C.*

been separated from it, and applying to both, conductors connected with the pile, effects have been produced which seemed at first miraculous. There are few muscles that retain their sensibility to the galvanic action longer than the diaphragm; in the heart and the intestines it is the same. I know not why the internal muscles have been held by many authors to be insensible to this kind of excitation. I have seen them constantly obey it, and many experiments, made publicly in my lectures, have always afforded me this result.*

CLXXIV. *Nature and medical uses of galvanism.*—Since the publication of the early editions of this work, there has been an accession of new facts to those already known. Volta came to Paris: he gave an exposition of his doctrine in several memoirs read before the National Institute of France, and he repeated before a committee the principal experiments on which it is founded. They have appeared so conclusive, that the theory of this illustrious philosopher has been unanimously adopted; and at this day all men of science admit the entire identity of the phenomena of galvanism and those of electricity. Certain bodies therefore in nature, and especially metals, possess the property of electrifying themselves, that is to say, of producing the greater part of the phenomena which denote the accumulation of electricity in a body, such as shocks, sparks, irritations, &c. merely by contact.†

It may be thought that galvanism, being only a new form of electrical action, ought to be confined to books of natural philosophy; and in fact, in the present state of things, it belongs rather to the physico-chemical sciences than to those of the animal economy. However, the galvano-electric irritation produces on our organs effects more decided than electricity. It seems to have more intimate relations with the animal economy; accordingly, it has been endeavoured to bring it into use in the treatment of disease. The experiments made by MM. Halle and Thillayė prove, that the effects of the pile penetrate and affect the nervous and muscular organs more deeply than the common electrical apparatus; that they provoke lively contractions, strong sensations of pricking and burning, in parts which disease has rendered insensible to electrical sparks, or even shocks. A man whose muscles on the left side of his face were all paralysed, found no effect from the electrical shock. He was exposed to the action of a pile of fifty plates, by communications through chains and metallic exciters of the two extremities of the pile, with different points of the cheek affected. At the moment of contact all the muscles of the face became convulsed with heat, pain, &c. These endeavours, repeated during more than six months, have, by degrees, brought back the parts to their natural state.

Dr. Alibert has applied galvanism with still more decided success to a priest attacked with hemiplegia. This patient, who lay in the wards of the hospital of St. Louis, has recovered the use of the palsied side sufficiently to walk, almost without assistance, and to use his right arm as he wants it. The treatment has gone on for several months: the pile employed consisted of fifty plates of zinc and copper. I am trying the same apparatus upon a Swedish officer, for incomplete deafness, which has hitherto resisted all known applications administered in different parts of Germany. Strong electrical shocks, recommended by Hufeland, had dispelled, in great measure, the hardness of hearing; but this amendment was only temporary: it ceased with the application of the remedy. The first trial of galvanism was attended

* See the Note in the APPENDIX on the subject of Galvanism, for observations as to the effects of this agent on some of the animal textures.—*J. C.*

† See APPENDIX, Notes K K, for an account of some recent views respecting the Relations and Agencies of Galvanism, &c.

with the same effect. The extremity of a conductor being placed in the exterior auditory duct of the right side, (moistened with a solution of muriate of ammonia, as well as the pieces of cloth which made part of the pile,) the left hand, dipped in the same liquid, touched a conductor placed at the copper pole; immediately an irritation, followed by painful prickings, was felt in the ear, the outer part of which became very red. The brain partook in the excitement, the eyes flashed, and the effect was such, that after remaining a few minutes in the closed galvanic circle, the patient was taken with a sort of inebriation. I propose to direct, as has been done at Berlin, a more immediate irritation on the right ear, which is the deafest, by introducing behind the velum pelati, on the guttural orifice of the Eustachian tube, the button which is at the end of the conductor of the zinc pole: or else to make this extremity correspond with a denuded surface, by a blister behind the diseased ear.

To use galvanism in paralysis of the bladder, it would be necessary to place the conductor of the zinc pole in the rectum, that of the other pole answering to a blister applied above the pubis, or else to the upper part of the thigh. In women, the vagina would be preferable to the rectum; the soft tissues which perform the part of moist conductors fulfilling that office the better the thinner they are. Galvanism is therefore an energetic stimulant of the vital powers; it may be employed with great advantage in all palsy, both of sensation and of motion. It acts as a stimulant, reddening the skin where it is applied, by determining thither the flow of blood, with heat. Monro could make his nose bleed at pleasure, by applying it to the pituitary membrane. I have made various experiments, having in view to establish the efficacy of galvanism in white swelling of the joints, and in ulcers which require excitement, such as those which are attended with a scorbutic affection, &c.: in all these cases it acts as a resolvent and as a tonic. I shall communicate, in my Surgical Nosography, the results of these attempts. Cases of asphyxia are those in which the greatest good may be hoped from galvanism, provided the application be made before all the vital heat be extinct.*

Those who would wish fuller details on galvanism, and on its possible application to the treatment of disease, will do well to consult the Complete History of Galvanism, by Professor Sue; the eulogium of Galvani, by Dr. Alibert, in the beginning of the fourth volume of the Memoirs of the Medical Society of Emulation; and the work of Dr. Aldini, nephew to the celebrated author of the discovery.†

CLXXV. *General view of the osseous system.*—Man, as well as the other red-blooded animals, (the mammiferæ, birds, reptiles, and fishes,) has an internal skeleton, formed of a great number of bones articulated together, and set in motion by the muscles with which they are covered. The white-blooded animals have no internal skeleton, and are enveloped in hard, scaly, or stony parts, forming what is called their outer skeleton. Some animals are entirely destitute of hard parts: this is the case with the zoophytes, and some worms and insects. The internal structure of bones is composed of nearly the same materials in all animals; viz. gelatine and salts containing a calcareous basis. The external skeleton of white-blooded animals bears a much greater resemblance to the epidermis than to the osseous system of the

* Dr. Philip is of opinion, that in those diseases in which the original cause of derangement is in the nervous ramifications or spinal cord only, where the sensorial functions are entire, and the vessels healthy, and the power of secretion is alone in fault, galvanism will often prove a valuable means of relief. He has frequently employed it in habitual asthma, "and almost uniformly with relief." He also recommends this active agent in a torpid state of the biliary functions, and in indigestion. See Treatise on Indigestion, third edition.—*J. C.*

† See APPENDIX, Notes K K, for some farther remarks respecting some of the Physiological and Physical Relations of Galvanic Electricity.—*J. C.*

red-blooded animals. Like the epidermis, it undergoes changes of decomposition and renovation. Thus, the lobster parts with its shell every year, when the body of this crustaceous animal increases in size, and it is replaced by a new envelope, which is at first very soft, and which gradually acquires the same consistence as the former. Lastly, the skeleton of birds differs from that of all other animals, in having its principal bones pierced by openings communicating with the lungs, and always filled with an air rarefied by the vital heat, which greatly assists in giving to them that specific lightness so essential to their peculiar mode of existence.

The osseous system serves as a foundation to the animal machine, yields a firm support to all its parts, determines the size of the body, its proportion, its form, and attitude. Without the bones the body would have no permanent form, and could not easily move from one place to another. When, from the loss of the calcareous earth to which they owe their hardness, these organs become soft and the limbs deformed, standing and the different motions of progression become, after a time, nearly impossible. Such are the effects of rachitis, a disease of which the nature is well understood, though we are not the better informed with regard to the manner in which its causes operate, or as to the medicines requisite to its cure.

The vertebral column forms the truly essential and fundamental part of the skeleton: it may be considered as the base of the osseous edifice, as the point in which all their efforts terminate, as the centre on which all the bones rest in their various motions, since every effort or shock, in any way considerable, is felt there. Moreover, it contains, in the canal with which it is perforated, the cerebral prolongation, which furnishes most of the nerves in the body.

In order that it may support all the different parts, and at the same time protect the delicate organ which it contains,* and adapt itself to the various attitudes required by the wants of life, it was necessary that the vertebral column should possess, besides great solidity, a sufficient degree of mobility: it possesses both these advantages, and owes the former to the breadth of the surfaces by which its bones are articulated together, to the size, the length, the direction, and the strength of their processes, and to the great number of muscles and ligaments connected with it; and it owes its freedom of motion to the great number of bones of which it is formed. Each single vertebra has but a slight degree of motion; but as they all have power of moving at once, the sum of their individual motion added together, gives as the result a general motion which is considerable, and which is estimated by multiplying the single motion by the number of vertebræ.

The centre of the motions, by which the spine is extended or bends forward or backward, is not situated in the articulation of the oblique processes, as is maintained by Winslow, in the Memoirs of the Academy of Sciences for the year 1730, nor in the intervertebral substance. The extension and flexion of the vertebræ are not performed on two centres of motion, the one in the intervertebral substance, the other in the articulation of the articulating processes, as was imagined by Cheselden and Barthez, but on an axis crossing the bone between its body and its great aperture. The anterior part of the bone, and its spinous process, perform, around this imaginary axis, mo-

* The peculiar manner in which the vertebræ grow, is itself accommodated to the delicacy of the spinal marrow; consisting, for a considerable length of time, of several pieces divided by cartilages, the circumference of the opening in these bones becomes enlarged with the enlargement of the spinal marrow, as we grow older. The circumference of the foramen of the occipital bone and that of the first vertebræ, which correspond to the thickest part of the spinal marrow, is, on that account, formed of four distinct pieces separated by cartilages in the first of these bones, and of five pieces in the other.

tions forming part of a circle, and which, though limited, are not the less marked; and in these motions the articulating surfaces, separated by the intervertebral substance, are brought into close contact, and this substance is compressed, while the oblique processes move on each other, and tend to part from one another: this is what happens in bending the trunk, while in straightening it, the anterior surfaces are removed from each other, the posterior surfaces approach, come closer and closer together, and finally touch throughout the whole of their extent, when the extension of the trunk is carried as far as the spinous processes will allow.

The use of the ridge of projections which arise from the posterior part of the vertebræ, is to limit the bending of the trunk backwards, and to enable the muscles which straighten it to act with a more powerful lever. When, from an habitually erect posture, these processes have been prevented from growing in their natural direction, the trunk may be bent backward to such a degree that the body forms, in that direction, an arc of a circle. It is thus that they train, from the earliest infancy, the tumblers who astonish us by the prodigious suppleness of their loins, in bending backward so as to change the natural direction of their spinal processes.

It was of consequence that the motions of the vertebral column should take place at once in a great number of articulations, as the curvatures are thus less sharp; and hence the organisation of the spinal marrow, which is very delicate, is not injured. The fibro-cartilaginous substances which connect together the bodies of the vertebræ, between which they lie, possess a remarkable degree of elasticity, like all bodies of the same kind, and support, in a favourable manner, the weight of the body. When the pressure which they experience is long continued, they somewhat yield and diminish in thickness, and this effect taking place at the same time in all the intervertebral substance, our stature is sensibly lowered. The body is, on that account, always shorter in the evening than in the morning; and this difference may be considerable, as is mentioned by Buffon to have been the case in several instances. The son of one of his most zealous coadjutors, (M. Gueneau de Montbeillard, to whom is due the greatest part of the natural history of birds,) a young man of tall stature, five feet nine inches when he had reached his complete growth, once lost an inch and a half after spending a whole night at a ball. This difference in the stature depends likewise on the condensation of the cellular adipose tissue at the heel, which forms, along the whole of the sole of the foot, a pretty thick layer.

The thigh bone is longer in man than in quadrupeds, and this relative length of the thigh gives him exclusively the power of resting his body by sitting.

The tibia is the only bone of the leg which affords a support to the body. The fibula, situated at its outer part, too thin and slender to support the weight of the body, is of use merely with regard to the articulation of the foot, on the outside of which it lies. It supports the foot, and prevents its starting outward by too powerful an abduction. The foot, in this motion, is forced against the fibula, which is bent outwardly, the more so when the person is advanced in years, and has, therefore, called into frequent action this force of resistance. Animals that climb, as the squirrels, whose feet are in a continual state of abduction, have a very large and strongly curved fibula.*

* This curvature is well marked in the chefs-d'œuvre of antique sculpture, and gives to the lower part of the leg, in our most beautiful statues, a thickness which does not at all agree with our present notions of elegance of form. This seems to me to prove that the beautiful is not invariable, as has been asserted by many philosophers; and that ideal perfection is not precisely the same in all ages, in nations equally civilised. The truth of this observation may be proved by the Apollo Belvedere: his knees are rather large and close together; and this

The number of the parts which form the feet, besides giving to these parts a greater solidity, is further useful in preventing the foot from being too violently shaken by striking the ground in our various motions of progression. In leaping from a height, we endeavour to fall on our toes, that the force of the fall may be broken, by being communicated to the numerous articulations of the tarsus and the metatarsus, and may not affect the trunk and head with a painful and even dangerous concussion. It is well known, that when the whole sole of the foot strikes against the ground in falls, fracture of the neck, of the thigh bones, and concussion of the brain and other organs, is not an unlikely consequence.

CLXXVI. *Structure of the bones.*—Whatever difference there may, at first sight, seem to exist between a bone and another organ, their composition is the same. Its structure consists of parts that are perfectly similar, with the exception of the saline inorganic matter which is deposited in the cells of its tissue, giving it hardness and that solidity which constitutes the most striking difference that distinguishes it from the soft parts. This earthy substance may be separated by immersing the bone in nitric acid diluted in a sufficient quantity of water. It is then found that it is a phosphate of lime, which is decomposed by yielding to the nitric acid its calcareous base. The bone, thus deprived of the principle to which it owes its consistence, becomes soft, flexible, and resembles a cartilage, which is resolvable, by long maceration, into a cellular-tissue similar to that of the other parts. This tissue contains a pretty considerable number of arteries, veins, and lymphatics. The bones are, therefore, mere cellular parenchymas, whose areolæ contain a crystallised saline substance, which they separate from the blood, and with which they become incrusted, by a power inherent in their tissue, and peculiar to it. The same result may be obtained by inverting the analysis. If a bone is exposed to boiling heat, for a few hours, in Papin's digester, all its organised parts become dissolved, melt, and furnish a quantity of gelatine, after which there remains only an inorganic saline concretion, which may likewise be obtained in a separate state by calcining the osseous part. The different proportions of the saline to the organised part vary considerably at different periods of life: the bones of the embryo are at first quite gelatinous. At the period of birth, and during the first years of life, the organic part of the bone is in greater proportion; the bones are less apt to break, more flexible, possessed of more vitality, and, when fractured, are more speedily and more easily consolidated. In youth, the two constituent parts are nearly in equal quantities; in adults the calcareous earth* alone forms two thirds of the osseous substance. At last, gradually increasing in quantity, it displaces in old people the part that is organised; hence their bones are weaker, more liable to fracture, and unite less readily. One may therefore say, that the quantity of phosphate of lime deposited in the bones is in the direct ratio of the age; and that, on the contrary, the energy of the vital faculties of these organs, their flexibility, their elasticity, their aptitude to become consolidated when their continuity is destroyed by accidents, are in an inverse ratio.

Anatomists distinguish in bones three substances, which they term compact, spongy, and reticular. The first, which is the hardest, collected in the centre of the long bones, where the greatest stress of the efforts applied to

form is the most beautiful representation of Nature, which gives to the femur an obliquity inwards, the knees not being perfectly straight, and without any disproportion between the calf and the thin part of the leg.

* By chemical analysis of the bones, there have been discovered several other saline substances mixed with the phosphate of lime; but as this salt alone constitutes the greatest part of the substance which gives to the bones their hardness, it has been particularly adduced. For an account of the Chemical Constitution of the Osseous Texture, see the Chapter at the end of the APPENDIX.—*J. C.*

their extremities rests, gives to the bone the strength which it required. Its formation has been explained in various ways: some have maintained that it owed its hardness to the pressure applied to its middle part by the two extremities of the bone, in the same manner as the stalk and the roots press against the *collet** of a plant. Haller thinks it is caused by the pulsations of the nutritious arteries which penetrate into the long bones at their middle part: why, then, is their structure different at their extremities where they receive arteries equally large and more numerous? In the process of ossification, this substance appears first in the centre of the long bones:† and this circumstance confirms the assertion of Kerkringius, who says, that our long bones begin to ossify in those points where they have to resist the greatest pressure.

The spongy substance is found within the short bones, and at the extremities of the long ones, where its accumulation is attended with two advantages,—that of giving to the bone, without increasing its weight, a considerable size, by which it may be articulated with the neighbouring bones by wide surfaces, so as to give firmness to their connexion: this conformation is attended with another advantage, that of avoiding the parallelism of the tendons which pass over the joints, in order to enlarge the angle of their insertion in the bones, and to give more efficacy to muscular action. The mechanical hypotheses proposed by Haller and Duhamel, to explain the formation of this spongy substance, are very unsatisfactory, especially if it be considered, that in the gelatinous bones of the embryo, the place that is to be occupied by the spongy substance, viz. the extremities of the long bones, of which the rudiments begin to appear, are larger than any other part. All the cells of this spongy substance communicate with one another, they are lined by a very fine membrane, and contain the medullary fluid. The laminæ, which cross each other in various directions, and which form the parietes of the cells, become fewer in number, and thinner; the spongy tissue expands in approaching the middle part of the bones, and forms (within the medullary canal of the compact substance) a reticular tissue, the use of which is to support the membranous tube containing the marrow.

These three substances, notwithstanding their unequal density, are in reality but one and the same substance differently modified. The reticular and spongy differ from the compact in containing less phosphate of lime, and in having a rarer and more expanded tissue. In other respects, those changes in the osseous tissue which constitute the laminated exostoses, the conversion of the bones by acids into a flexible cartilage, which by maceration may be reduced into cellular tissue, prove that these three substances are truly identical, and differ from each other only by the degrees of closeness of their texture, and the quantity of calcareous phosphate deposited in the meshes of their tissue.

The compact substance appears to consist of concentric laminæ, strongly united together, and to be formed of fibres arranged longitudinally, and in juxta-position. In proof of this arrangement, it is usual to mention the exfoliation of bones exposed to the air; but these laminæ, detached from an exfoliating bone, merely prove that the action of the disease, the air, heat, or any other agent, by applying itself successively to the different layers of bone, produces between them a separation which did not exist in health, and determines their falling off in succession. Certain parts, in which this lamellated structure does not exist, may, in like manner, undergo the same kind of decomposition. Thus, Lassone saw a piece of human skin, that had been pre-

* The part where the stem joins the root.—*T.* † See APPENDIX, Notes L L.

served for a considerable length of time in a vault, separate into layers of extreme minuteness.

The vital principle which exists, in a smaller degree in the bones than in other parts, seems to animate, to a certain extent, their different substances. Proportioned to the number of vessels which are distributed to it, life is more active in the spongy tissue of the bones than in their denser parts; hence, in fracture of this part, fleshy granulations and callus form more quickly. Caries likewise advances more rapidly, and it is more difficult to interrupt its progress.

CLXXVII. *Of the uses of the periosteum and of the medullary juices.*— Whatever be the situation, the size, the shape, and the composition of bones, they are all enveloped by the periosteum, a whitish, fibrous, dense, and compact membrane, to which are distributed the vessels which penetrate into their substance. The periosteum is a membrane perfectly distinct from the other soft parts, and from the bone itself, to which it adheres by means of vessels and of cellular tissue, which pass from the one to the other the more closely as we are more advanced in years. The cellular and vascular fibres that penetrate into the substance of the bone, establish a very close sympathetic connexion between its periosteum and the very delicate membrane that lines its internal cavity, which secretes the marrow, and is called the internal periosteum. On destroying the internal medullary membrane, by introducing a stilet within the cavity of the bone, its external layers swell, are detached from the inner ones, and form, as it were, a new bone around the sequestra. The new bone is not formed by the ossification of the periosteum, as was maintained by Troja. This membrane has no more to do with the formation of the new bone in necrosis than with that of the callus in fracture.* The periosteum covering a bone affected with necrosis does not become thicker, and does not acquire more consistence; nor is there formed around the ends of a fractured bone a ring to keep them cemented, as was the opinion of Duhamel; an opinion recently brought forward in a work in which the author seems to delight in reviving errors that have been abandoned for ages. Destitute of nourishment, dead and dried up in this artificial necrosis, the sequestra moves in the centre of the new osseous production, from which it may be extracted by a perforation made for that purpose. It is owing to the same sympathy that the dull, nocturnal pains, which are occasioned by the warmth of the bed, in patients in the last stages of the venereal affection, and which appear to have their seat in the centre of the long bones, occasion a swelling of these bones and of the periosteum.

The use of the periosteum is to regulate the distribution of the nutritious juices of bones, since, whenever it is removed, granulations arise, in an irregular manner, on the spot that is bared. This quality is, besides, common to all fibrous membranes, whose destruction is followed by excrescences from the organs which they cover. The same take place whenever trees are partially stripped of their bark. It has been erroneously believed that the periosteum, in the same way as the bark of plants, contributes to the growth of the bones by the successive induration of its internal laminæ.

The marrow which fills the central cavity of the long bones, and the me-

* The manner in which the new bone acquires a periosteum, in cases of the regeneration of this texture, is a matter of much interest and doubt. In the examination of some specimens, Dr. Knox observed a thin membrane covering the osseous granulations; but he knew of no facts to decide whence this membrane proceeds. "It is not unlikely," he remarks, "that it is supplied by the cellular texture either of the new bone or of the surrounding parts; and that in some instances it may be merely a prolongation of the old. New skin on ulcers does not always grow from the surrounding healthy edges; which fact may be applied to the formation of new periosteum."—*J. C.*

dullary fluid contained in the cells of the spongy substance, bear the greatest analogy to adeps, both in their chemical composition and in their uses (CVI.) The proportion of these two fluids is uniformly relative. In very thin people, the bones contain a marrow that is thin and watery; and though this fluid always fills the internal cavities of these organs, whose solid parietes cannot collapse, it contains much fewer particles in the same bulk; and its quantity, like that of the fat, is in fact diminished. It is the product of arterial exhalation, and does not serve to the immediate nutrition of the bone, as was thought by the ancients; at least, it does not answer that purpose solely, for in the numerous class of birds the bones contain cavities for air, and are destitute of this fluid. It is difficult to determine the use of the marrow and of the medullary fluid: may they not answer the purpose of filling the cavities which nature has formed in the bones, so as to render them lighter? Does a part of these fluids exude through the cartilages of the joints, and mix with the synovia, to increase its quantity and to lessen the friction of the articulating surfaces? If this transudation may take place after death, why might it not take place when all the parts are in a state of vital warmth and expansion?*

CLXXVIII. *Of the articulations, the articulating cartilages and ligaments, and the synovial fluid.*—The articulations of the different parts of the skeleton are not all intended to allow of motion; several, as the serrated and squamous sutures, and the gomphosis, or the junction by engrafting, are entirely without motion, and are, on that account, termed *synarthrosis.* All the other articulations, whether the bones are in immediate contact (diarthrosis of contiguity), or whether they are united by a substance interposed between them (diarthrosis of continuity or amphiarthrosis), are endowed with a certain degree of mobility. I shall speak merely of the movable articulations; whether they allow of extensive motions, and in every direction (diarthrosis orbicularis), or whether the bones move only in two opposite directions (alternate diarthrosis or ginglymus), by forming an angle (angular ginglymus), or by executing on each other motions of rotation (lateral ginglymus).

In all the articulations the osseous surfaces are covered by laminæ of a

* The marrow of the bones is contained in the medullary membrane. This latter substance may be easily detached from the bone. It resembles, in some respects, a cobweb, being pierced by a number of holes. It is formed of cellular tissue and of vessels. The former is very delicate and rare, and evidently performs the function of furnishing a surface for the ramification of the vessels. Some of these vessels are ramified externally, proceeding directly from the medullary membrane to the osseous texture surrounding it, and thus performing the office of an internal periosteum to the bone; others are distributed internally, and in the direction of the axis of the bone, to the medullary membrane itself, and to the spongy extremities of the bones. The principal artery of the medullary canal is surrounded by absorbent vessels at its entrance into this canal. A plexus of nerves may be also observed to surround the artery in the same situation, and to dip into the bone at the place nearest to the arterial trunk.

The adipose vesicles, which contain the marrow and occupy the interior of the medullary membrane, are the same in kind as those of the cellular texture, although less distinct. Authors have long since stated that those adipose vesicles are united *en grappe*, and many believe that they communicate directly with each other.

M. Beclard considers the marrow to consist of seven parts out of eight of an oleaginous matter in fat subjects, which accords with the opinion of Grutzmacher; while this substance, in a phthisical patient, was found to consist of only a fourth part of fatty matter, the rest being a serous or albuminous-like fluid.

The marrow does not exist in the fœtus, and even the medullary membrane itself cannot be recognised previous to ossification. As this process advances, the medullary canal begins to be formed; and at first the nutritious artery nearly fills it. At a later period this artery is seen ramified on the parietes of this cavity, and in the situation of the medullary membrane. The marrow becomes abundant as age advances, owing to the enlargement of the medullary cavity.

The sensibility of the marrow, which was contended for by Duverney, but since denied, is considered by M. Béclard really to exist, and to be satisfactorily shewn, when some time is allowed to elapse between the pain of the operation necessary to expose the marrow, and the experiment to which it is to be subjected in order to ascertain the fact as to its sensibility. See APPENDIX, Notes L L., for additional remarks on this subject.—*J. C.*

substance less hard than that of the bone. These are the articulating cartilages, which answer the two purposes, of giving to the ends of the bones the degree of polish necessary to their slipping freely, and to facilitating motion, by the considerable degree of elasticity which they possess. Morgagni has shewn that, of all animal substances, cartilages possess most elasticity: their structure is very different from that of the bones, even when these are yet cartilaginous; for these articulating cartilages do not become ossified even in persons greatly advanced in years.* They are formed of very short fibres, disposed according to the length of the bone, strongly compressed against each other, and united by other transverse fibres. This vertical direction of the greatest part of cartilaginous fibres, demonstrated by Lassone, is very favourable to their elastic reaction. The capsular ligament is reflected over them, becomes very thin, and is lost in their perichondrium, according to Bonn, Nesbith, and other anatomists.

Besides the cartilages which surround the extremities of bones, there are found, in certain articulations, fibro-cartilaginous laminæ lying between the articulating surfaces. These connecting ligaments may be observed in the articulation of the lower jaw to the temporal bones, of the femur with the tibia, and of the sternum with the clavicle; and all such articulations perform a great number of motions, as is the case with the jaw; or suffer considerable pressure, as the joints of the knee and sternum. The latter, which has a very slight degree of motion, being the point in which terminate all the efforts of the upper extremity, required this apparatus to lessen the effect on the trunk, the motion that is given being in part lost in the action of the articulating cartilage.†

I shall not repeat what has been already said of the secretion of the fluid that lubricates the articulating surfaces, that facilitates their motion, and keeps them in contact. Its quantity is in the direct ratio of the extent of these surfaces, and of the membranous capsule in which they are contained; it is, likewise, proportioned to the frequency of motion which each articulation allows.

Synovia is the name that is given to the fluid prepared by the glandulo-cellular bodies in the vicinity of the articulations, and secreted by the membranous capsules which surround them, and are reflected over the articulating extremities of the bones whose cartilages they cover; so that, as was shewn by Bonn, about the middle of the last century, these extremities cannot be said to be contained within the cavity of the capsule, which is closed in every direction, any more than the abdominal viscera within that of the peritoneum. The synovia is heavier than common water, quite colourless, and more viscid than any other animal fluid. It contains a considerable quantity of albumen, which, according to Margueron, who first gave a tolerably accurate analysis of synovia, is found in a particular state, and much disposed to concrete into filaments on the addition of acids. Besides, it contains also muriate, carbonate, and phosphate of this secretion, which substances are dissolved in the watery part of this secretion, which forms about three-fourths of its weight.‡

* Sometimes, however, these cartilages are destroyed; the denuded bone then becomes polished by friction, and as hard as ivory.

† The most certain proof of the organic nature of the cartilages is the serous exudation which appears in the course of a few seconds after a clean division of them by the knife. Cellular texture forms the mould or basis in which the cartilaginous substance is deposited. The vessels of this texture carry only the colourless part of the blood into it, during its ordinary state of health; yet it is remarkable that other colouring substances, as bile and madder, give this substance their respective colours.—*J. C.*

‡ See the Chapter on the Chemical Constitution of the Secretions, &c. at the end of the Appendix.

CLXXIX. *Theory of anchylosis.*—Motion may be considered as the proper stimulus of the synovial secretion ; and a movable joint, as is justly observed by Grimaud, is as a centre of fluxion towards which the fluids rush in every direction, in consequence of the irritation which friction determines. If the joint remains long without motion, the synovia is secreted in smaller quantity, and this lessens gradually : it may even happen that the articulating surfaces, remaining long absolutely motionless, lose their moisture, and, from the want of the fluid which should lubricate them, bring on irritation and adhesive inflammation in each other, either from increased action of the vessels of the perichondrium, or, as is believed by Nesbith, Bonn, and others, from an inflammatory state of the fold, which is reflected from the capsule of the joint over the ligament.

This is the manner in which the disease termed anchylosis comes on ; a disease improperly ascribed to the congestion of the soft parts, and especially of the ligaments surrounding the articulations. In fact, when in a fracture of the thigh or leg, about the middle of the length of one of these bones, and consequently at the greatest possible distance from the knee-joint, the circumstances of the case require that the bandages should be kept on the limb a considerable time, the joint loses its power of motion, recovers it with difficulty, and sometimes not at all. I have at present before me the case of a man in whom a scorbutic affection has delayed to such a degree the union of the bone, after a simple fracture of the femur, about its middle, that it has been found necessary to continue, for seven months, the use of splints. In the course of so long a state of inaction, the soft parts have lost the habit of moving, and the knee is almost anchylosed.

Whenever, on account of any complaint, one has been confined to bed, the first attempts to walk are painful, difficult, and attended by a marked crepitus in the knee, denoting clearly the want of synovia. If the joint be examined in a person who before death has been long without motion, the articulating surfaces will be found rough and dry, with evident marks of inflammation. Flajani mentions the case of a patient who died after having been three months in bed in an almost motionless state. Externally the knees did not appear to have been injured, and yet he could not bend his knee-joints. On opening these joints, it was found that the articulating surfaces had grown together ; the posterior part of the patella adhered to the condyles of the femur, and it was necessary to use a scalpel to detach these parts from each other. I have frequently observed the same appearance in dissecting the knee-joint of persons who died while labouring under white swelling, with or without ulceration. The anchylosis which invariably attends this affection, evidently arises from the absolute rest of the diseased joint.

Anchylosis from want of motion, and consequently from want of synovia, is not always a partial affection, limited to one or two joints ; sometimes it affects several at once, as in the case of the patient whose skeleton was presented by M. Larrey to the museum of the School of Medicine at Paris. One of the most remarkable cases of universal anchylosis of the joints is that lately communicated to the National Institute by M. Percy : the patient was an old cavalry officer, who was subject to fits of the gout, and whose articulations, even that of the lower jaw, became stiff, and completely lost all power of motion, so that, towards the latter end of his wretched existence, he could not be moved without feeling severe pain in his anchylosed joints.

From this explanation may be conceived the advantage of moving the lower extremity, when, after a fracture of the leg, the ends of the bone have become sufficiently united to prevent their being displaced. These motions, which are of indispensable necessity in all fractures of the femur, of the

tibia, and especially of the patella, are much better calculated to prevent anchylosis than the various resolvent remedies which are commonly employed, as plasters of soap, vigo, cicuta, diabotanum, diachylon, pumping, bathing, and fumigations, which, however, should be used in combination with a moderate exercise of the limb, in order to obtain the most complete success.

The gout affects those joints which are most subject to motion, and on which there is the greatest pressure. The first attacks, as Sydenham observes, come on in the joint of the great toe with the first metatarsal bone; an articulation which bears the weight of the whole body, and which is most called into action in the various motions of progression.

The muscles which pass over the joints give them much greater security than the lateral ligaments. In fact, if the muscles become palsied, the mere weight of the limb stretches the ligaments, which give way, become elongated, and allow the head of the bone to escape from its glenoid cavity. It is in this manner that a loss of motion and atrophy of the deltoid muscle are attended with a luxation of the humerus: the orbicular ligament of the articulation of this bone with the scapula being incapable of retaining its head within the glenoid cavity. The spinal column, when dissected and deprived of all but its ligamentous attachments, gives way under a weight much smaller than that which it would have supported before being stripped of the muscles which are connected with it.

CLXXX. *Of standing, &c.*—This is the name given to the action by which man holds himself upright on a solid plane. In this erect position of all our parts, the perpendicular line, passing through the centre of gravity* of the body, must fall on some point of the space measured by the soles of the feet. Standing is most firm when, on prolonging the line of the centre of gravity of the body, it falls on the base of sustentation, (I call thus the space defined by the feet, whether close or apart); but this line may tend to exceed it, without our necessarily falling, the muscular action soon restoring the equilibrium, which is deranged by the altered direction of this line. But if the lower extremity of the line, by being prolonged, should be without the limits of the base of sustentation, a fall is unavoidable on the side towards which this line inclines.†

If the body is inclined backwards, so that there is a danger of a fall on the occiput, the extensor muscles of the leg contract powerfully to prevent the thigh from bending, while other powers bring forward the upper parts, and give to the prolonged line of the centre of gravity a different direction: and if, in proportion as the extensors of the leg are brought into action, its inclination be increased to such a degree that nothing is capable of keeping up the body, which its own weight tends to bring to the ground, these muscles, by a motion proportioned to the quickness of the fall, will increase their efforts to prevent it, and may be able, in that violent contraction, to snap asunder the patella, as I have explained in a memoir on the fractures of that bone.

I think it useful to insist, more than has been done hitherto, on the mechanism by which the human body is supported in the erect posture; for a

* The centre of gravity in the adult is situated between the sacrum and pubis.

† "*Quotiescumque linea propensionis corporis humani cadit extra unius pedis innixi plantam, aut extra quadrilaterum, comprehensum à duabus plantis pedum, impediri ruina, à quocumque musculorum conatu, non potest.*"—BORELLI, *Prop.* 140.

The firmness of the attitude in standing depends in part, therefore, on the breadth of the feet and on their distance; hence it is much more tottering when we stand on one foot; and we are, under such circumstances, obliged to be perpetually struggling to prevent the centre of gravity from falling out of the narrow limits of the base of sustentation.

knowledge of that mechanism facilitates the explanation of the motions of progression. To walk or to run, the body must be upright: now, when it is known by what power the centre of gravity of the body is maintained perpendicular on the plane which supports it, it will be easy to understand the different ways in which it changes its place in the course of locomotion.

Let us first inquire into the question so long agitated, whether man is intended to support himself, and to walk on his four limbs, in the early period of his existence after birth?

CLXXXI. *Of the mechanism of standing.*—An upright position would be to man a state of rest, if his head were in a perfect equilibrium on the vertebral column; and if the latter, forming the axis of the body, and supporting equally in every direction the weight of the abdominal and thoracic viscera, fell perpendicularly on the pelvis placed horizontally; and, in short, if the bones of the lower extremities formed columns set perpendicularly under their superincumbent weight; but not one of these circumstances is to be observed in the human body: the articulation of the head does not correspond to its centre of gravity, and the weight of the thoracic and abdominal viscera, and of the parietes of the cavities in which they are contained, rests almost entirely on the anterior part of the vertebral column. The vertebral column is supported on an inclined base, and the bones of the inferior extremities, which are connected to each other by convex and slippery surfaces, are more or less inclined towards one another. It is therefore necessary that an active power* watch incessantly, to prevent the fall which would be the natural consequence of their weight and direction.

This power resides in the extensor muscles, which keep the parts of our body in a state of extension the more perfect, and which render our erect posture the firmer, as they are endowed with a more considerable power of antagonism, and as our parts are naturally less disposed to flexion; and, besides, as we have seen (CLXVI.), these powers are not sufficient to balance those whose action is directly opposed to theirs.

The relative weakness of the extensor muscles is not the only obstacle which renders impossible an erect posture at an early period of life. Other causes, into which we are about to enter, concur in unfitting the new-born child for the exercise of that faculty.

The articulation of the head to the vertebral column being nearer the occiput than the chin, and not corresponding to its centre of gravity, its own weight is sufficient to make it fall on the upper part of the chest. It is the more disposed to fall forward from its greater bulk; and as, in a new-born child, the head is much larger in proportion than the other parts of the body, and as its extensor muscles partake of the greater weakness of that set of muscles, it falls on the fore part of the chest, and in its fall draws the body after it. The weight of the thoracic and abdominal viscera tends to produce the same effect.

Growth always proceeds from the upper to the lower parts, and this law,

* An upright posture is not in all animals, as it is in man, the consequence of an effort. This is proved by the following fact, observed by M. Dumeril:—the sea-fowl, and especially the waders (*Grallæ* Linn.), as herons and storks, that are forced to live in the midst of marshes and muddy waters, in which they find the fishes and reptiles on which they feed, have long since afforded matter of surprise to naturalists by the length of time they can remain motionless in an erect posture. This singular power, so necessary to animals obliged to expect their prey more from chance than from industry, they owe to a peculiar conformation of the articulation between the leg and thigh. The articulating surface of the thigh-bone, as M. Dumeril had an opportunity of observing in a stork (*Ardea ciconia* Linn.), contains in its centre a depression, into which there is received a projection of the tibia. To enable the animal to bend its leg, that projection must be disengaged from the depression into which it is lodged, and this is resisted by several ligaments, which keep the leg extended in standing, in flying, and other progressive motions, without the assistance of the extensor muscles.

which operates uniformly, completely eludes every kind of mechanical explanation. It is otherwise with regard to the effects which result from this unequal growth in respect to the erect posture. The inferior limbs, which serve as a base to the whole edifice, being imperfectly evolved at the period of birth, the upper parts placed on these unsteady foundations, must necessarily fall and bring them down with them.

The relative weight of the head, and of the thoracic and abdominal viscera, tends, therefore, to bring forward the line in the direction of which all the parts of the body press on the plane which supports it, and this line should be exactly perpendicular to that plane to enable the body to be perfectly erect. The following fact proves this assertion:—I have observed, that children whose heads are very large, whose bellies project, and whose viscera are loaded with fat, have much difficulty in learning to stand; it is only about the end of their second year that they dare trust to their own strength, and then they meet with frequent falls, and have a continual tendency to go on all fours.

The vertebral column in the child does not describe, as in the adult, three curves alternately placed in opposite directions. It is almost straight, and yet presents in the direction of its length a slight curvature, the concavity of which looks forwards. This incurvation, which depends solely on the flexion of the trunk while in the womb, is accordingly more marked the nearer the child is to the time of his birth.

It is well known that the curvatures in opposite directions to the vertebral column, add to the firmness of the erect posture, by increasing the extent of the space within which the centre of gravity may move, without being carried beyond its limits. With regard to that use, the vertebral column may be considered as defined by two lines drawn from the anterior and posterior part of the first cervical vertebra to the sacro-lumbari symphysis. These two lines, very near to each other at their upper part, and below, at a distance from each other, would be the chords of arcs, and the tangents of the curves formed by the vertebral column. So that this column may be considered as having a fictitious thickness greatly exceeding its real bulk.

In the new-born child the want of alternate curvatures not only contracts the boundaries within which the centre of gravity may be varied, but the direction of the only curvature which exists favours the flexion of the trunk, and, consequently, the inclination forward of the centre of gravity, and the tendency to fall in that direction. This inflexion of the vertebral column in the fœtus, and in the young child, resembles that observed in several quadrupeds.*

The disadvantage resulting from the want of alternate curvatures in the vertebral column of the child, is farther increased by the total absence of spinous processes. It is well known that the principal use of these projections is to place the power at a distance from the centre of motion of the vertebræ, to increase the length of the lever by which it acts in straightening the trunk, and thereby to render its action more efficacious. At the period of birth the vertebræ have no spinous processes; they afterwards grow from the place at which the laminæ of those bones are united by means of a cartilaginous substance, which completes the posterior part of the vertebral canal. The muscles destined to keep the trunk erect, weakened by its constant flex-

* This curvature is very distinctly marked in swine. The back of these animals is remarkably prominent; and this form, necessary to enable the vertebral column to support the immense weight of their abdominal viscera, has a considerable influence on the mechanism of their motions of progression. When frightened by any noise, they spring in bounds, and it is easy to perceive that, at each spring, the spine becomes arched and then straightens itself, and that their motion, when rapid, is effected by the alternate tension and relaxation of their spinal arch.

ion during gestation, lose, besides, a great deal of their power from the unfavourable manner in which they are applied to the part on which they are to act.

The flexion of the head does not depend merely on its very considerable weight, but likewise on the want of spinous processes in the cervical vertebræ, since the principal motions of the neck are performed, not so much by articulation with the atlas, as by the union of the other cervical vertebræ.

The pelvis of the child is but imperfectly evolved, and its upper outlet very oblique. The viscera, which are afterwards to be contained within its cavity, are, for the greater part, situated above it. This obliquity of the pelvis would require a perpetual straightening of the vertebral column to prevent the direction of the centre of gravity from obeying its natural tendency forward. On the other hand, the vertebral column, resting on a narrow pelvis, is less firmly fixed, and may more readily be drawn beyond the limits of the base of sustentation. Lastly, the limited extent of the pelvis, together with its obliquity, causes the ill-supported abdominal viscera to fall on the anterior and inferior part of the parietes of the abdomen, and favours the fall of the body in the same direction.

The patella, which answers the double purpose of giving firmness to the knee-joint, in front of which it is placed, and of increasing the power of the muscles of the leg, by placing them at a distance from the centre of motion in that articulation, and by increasing the angle at which they are inserted into the tibia, as yet does not exist in new-born children. The tendinous portion of the extensors of the leg, where the patella is hereafter to be formed, is merely of a more condensed tissue, and of a cartilaginous hardness.

The want of a fulcrum is attended with a continual disposition in the leg to bend upon the thigh, and the parallel direction of its extensor muscles occasions a complete loss of their effective power. Then their antagonising muscles induce a flexion of that limb, which is the more considerable, as it is but imperfectly limited by the tendon which is situated at the fore part of the knee.

The length of the os calcis, and the extent of its projection beyond the inferior extremity of the bones of the leg, tend to give firmness to the erect posture, by increasing the length of the lever by which the extensors of the foot act on the heel; and as in the new-born child this bone is shorter and less projecting, the power of these muscles, whose insertion is very near the centre of motion of the articulation of the foot, is greatly diminished.

The feet in man are broader than those of any other animal; and to this breadth of the surface of the base on which he rests, he in great measure owes the advantage of being able to support the weight of his body, on one leg or on both, in standing, and in the different motions of progression; while the other mammalia cannot support themselves, at least only for a limited time, without resting on three of their extremities. When I say that, from the extent of his feet, the body of man does, of all animals, rest on the broadest surface, I do not take into account the space which those parts include between them when apart from each other. In fact, the space which is measured by the feet, is much greater in quadrupeds than in man. Nature has made up for the disadvantage arising out of the smallness of their feet, by the distance at which they are placed; and if that form disables them from standing on two feet, it gives firmness to their peculiar mode of standing.

The feet of the ourang outang, which, in the general structure of his organs, bears so striking an analogy to the human species, resemble a coarsely formed hand, better fitted to climb the trees on which that animal seeks

his food, than to the purposes to which man applies his hands. Thus the erect posture, which he at times assumes, is neither the most convenient nor the most natural to him. And, according to a philosopher, who speaks on the authority of several travellers, if a sudden danger obliges him to make his escape, or to leap, he drops on all fours, and discovers his real origin: he is reduced to his own condition when he quits that unnatural attitude, and discovers in himself an animal, which, like many a man, has no better quality to recommend him than a specious disguise.

The feet are the parts least developed in the new-born child; his body is insecure on that narrow basis: the prolongation of the line of his centre of gravity, which so many other causes tend to carry beyond that base, will be the more inclined to fall beyond it from its small extent. The greater number of the differences which have just been examined, depend on the mode of nutrition in the fœtus. The umbilical arteries bring to the mother the blood which the aorta carries towards the lower parts, and only a few small branches are sent to the pelvis and to the lower extremities. Thus the development, which almost uniformly bears a proportion to the quantity of blood sent into organs, is but imperfect in those parts at the time of birth, while the head of the trunk and upper extremities are evolved much more considerably.

The new-born child, therefore, resembles quadrupeds in the physical arrangement of his organs. This analogy is the more marked the nearer the fœtus is to the period of its formation; and it might be laid down as a general proposition, that organised beings resemble one another more closely the nearer to the period of incipient existence they are examined. The differences which characterise them become apparent in proportion to the progress of evolution, and they are more and more distinct as the acts of life are repeated in the organs which it animates.

The unequal distribution of power in the muscles, and the unfavourable disposition of the parts to which these powers are applied, render it impossible for the infant to stand upright, that is, to keep the mean line of direction of his body nearly perpendicular to the plane which supports it. But in proportion as he advances in age, the preponderance of the flexors over the extensors ceases to be in excess. The proportionate size of the head, and of the thoracic and abdominal viscera, diminishes. The curvatures of the vertebral column begin to be distinguishable, the spinous processes of the vertebræ are evolved; the breadth of the pelvis is increased, and its obliquity lessened; the patella becomes ossified, the os calcis juts out backwards, and the relative smallness of the feet ceases. By degrees the child learns to stand, resting on both, or only on one of his feet, his eyes naturally directed towards heaven—a noble prerogative, which, if one might believe Ovid,* is possessed by man alone of all the animals.

Man is of all animals the only one that can stand upright and walk in that attitude, when his organs are sufficiently evolved. Let us now point out some of the principal causes to which that privilege is to be ascribed.

CLXXXII.—Though the articulation of the head to the cervical column does not correspond either to its centre of magnitude or to its centre of gravity, and though it is nearer to the occiput than to the chin, its distance from the latter is much smaller in man than in the monkey and other animals, whose foramen magnum is, according to Daubenton, placed nearest to the

* *Os homini sublime dedit, cœlumque tueri*
Jussit, et erectos ad sidera tollere vultus.

These verses may be much more justly applied to the fish called by naturalists *uranoscopus*. Its eyes are turned upwards, and constantly look towards the heavens.

posterior extremity of the head when they resemble man the least. The head, therefore, is very nearly in equilibrio on the column which supports it; at least, to keep it in that position, a very slight power is required; while the head of a quadruped, which has a constant tendency towards the ground, requires to be supported by a part capable of a great and continued resistance. This purpose is answered by the posterior cervical ligament, so remarkable in those animals, attached to the spinous processes of the vertebræ and to the protuberance of the occipital bone, which projects much more in them than in the human species, in whom, instead of a posterior cervical ligament, there is found a mere line of cellular substance, dividing the nape of the neck into two equal parts.

The alternate curvatures of the vertebral column, the breadth of the pelvis and of the feet, the great power of the extensors of the foot and thigh*—all these favourable conditions, observable in man, are wanting in animals; but as in the latter every thing concurs to prevent their being capable of standing on two feet, in man every thing is so disposed as to render it very difficult for him to rest on his four extremities. In fact, independently of the great inequality which there is between his upper and lower limbs, a difference of length which, being less sensible in early life, makes it less uneasy for a child to walk on his hands and feet, these four limbs are far from affording the body an equally solid support. The eyes being naturally forwards, are, in that attitude, directed towards the earth, and do not embrace a sufficient space.

We cannot, therefore, agree with Barthez, that man during infancy is naturally a quadruped, since he is then but an imperfect biped (CLXXXI.); nor can we admit that man might walk on all fours all his life, if he were not broken of the bad habit which he learns in infancy.

CLXXXIII.—Very little has been added to what Galen has said, in his admirable work on the structure of parts, relative to the respective advantages attending the peculiar conformation and structure of the upper and lower limbs. It is easy to see, that in combining, as much as possible, strength and facility of motion, nature has made the former predominate in the structure of the inferior extremities, while she has sacrificed strength to facility, to precision, to extent, and rapidity of motion, in the upper extremities.

To convince oneself of the truth of what has been stated, it is sufficient to compare, under the two relations† of the resistance of which they are capable, and of the motions which they allow, the pelvis to the shoulder, the thigh to the humerus, the leg to the fore-arm, and the foot to the hand.

The inferior extremities, if examined when the bones are covered with the soft parts, will present the appearance of an inverted cone or pyramid, which, at first sight, appears contrary to the object which nature had in view; but if the bones be stripped of their fleshy coverings, these solid supports will be seen to represent a pyramid, whose base is at the lowest part, and formed by the foot, and which decreases in breadth upward from the leg, formed by the union of two bones, towards the thigh consisting of only one bone.

If it be asked why the inferior extremities are formed of several pieces, detached and placed one above the other, it will be found that they are thereby much more solid than if formed of one bone, since, according to a theorem demonstrated by Euler,‡ two columns containing the same quantity of mat-

* These masses form the calf of the leg and the buttocks: in no animal are these muscles of flesh more prominent than in man

† See the anatomical observations on the neck of the thigh bone, which I have prefixed to a memoir bearing the title of *Dissertation Anatomico-chirurgicale sur les Fractures du Col de Fémur.* Paris, an VII.

‡ *Methodus inveniendi lineas curvas.*—Nature has, therefore, increased the number of these

ter, and of equal diameter, have each a solidity in an inverse ratio of the squares of their height; in other words, of two columns containing the same materials, of equal diameter, and of unequal height, the smaller is the stronger.

The long bones, which by their union form the inferior extremity, contain a cavity that adds to their strength; for, according to another theorem, explained by Galileo, two hollow columns of the same quantity of matter, of the same weight and length, bear to each other a proportion of strength measured by the diameter of their internal excavations.

The breadth of surface of the articulations of the inferior extremities assist materially in giving them additional strength, when, in standing, these bones are in a vertical direction. No articulation has a broader surface than that of the thigh with the leg and knee-pan. Among the orbicular articulations, no one has more points of contact than the joint of the thigh-bone to those of the pelvis. Professor Barthez says, that when the body is erect, the head of the thigh bone and the acetabulum of the os innominatum, which receives that bone, come in contact in a surface of small extent. I am, on the contrary, of opinion, that in no possible case can the contact of two bones be more complete. The middle line of direction of the upper part of the thigh-bone is then exactly perpendicular to the surface of the condyloid cavity, which embraces and touches, in nearly every point, the almost spherical head of that bone.

The cervix on which the head of the bone is placed, by keeping the thigh-bone at a distance from the cavity of the pelvis, increases the extent of the space in which the centre of gravity may vary without being carried beyond its limits.

CLXXXIV.—The erect posture does not imply a perfect absence of motion. It is, on the contrary, accompanied by a staggering, which is the more marked in proportion as the person has less strength and vigour. These perpetual oscillations, though but slightly distinct in a man who stands upright, depend on the incapacity of the extensors to keep up a constant state of contraction, so that they become relaxed for a short time; and the intervals of rest in the extensors are frequent in proportion to the weaker state of the subject.

Some physiologists have given a very inaccurate idea of standing, by making that attitude depend on a general effort of the muscles: the extensors only are truly active. The flexors, far from assisting, tend, on the contrary, to disturb the relation between the bones necessary to render that state permanent. This explains why standing is so much more fatiguing than walking, in which the extensors and flexors of the limbs are in alternate action and rest.

It may be said, nevertheless, that to give the greater firmness to the attitude, we sometimes contract, in a moderate degree, the flexors themselves; then, that great part of the real force of the muscles, which acts according to the direction of the levers which they are to set in motion (CLXVI.), and which is completely lost in the different motions which they produce, is usefully employed in drawing together the articular extremities, in keeping their

columns in the extremities of quadrupeds, by raising their heel, and the different parts of the foot whose bones she has lengthened, to make of them so many secondary legs. These numerous columns, placed above one another, are alternately inclined, and in a state of habitual flexion, in the quadrupeds remarkable for swiftness in running, or for their power in leaping, as in the hare and squirrel; while in the ox, and especially in the elephant, they are all placed vertically; so that the enormous mass of the latter rests on four pillars, the different pieces of which are short, and so slightly movable on one another, that, as Barthez observes, Saint Basil has adopted the error of Pliny, Ælian, and several other writers of antiquity, that there are no articulations in the legs of that monstrous animal.

surfaces firmly applied to each other, and in maintaining their exact superposition, which is necessary to the erect posture of the body. No one that I know of had taken notice of this exployment of the greater portion of our muscular power, which was thought completely lost by the unfavourable arrangement of our organs of motion.

The line, according to which all the parts of the body bear on the plane which supports them, has much more tendency to fall forwards than backwards ;* and falls forward are the most common and the easiest. Thus, nature has directed, in the same direction, the motion of the hands, which we carry forward to break the force of our falls, to prevent too violent shocks, and to lessen their effect. At the same time she has provided means of protection towards the sides, which the hands could not guard. She has given more thickness to the back part of the skull ; the skin which covers the neck and back is much denser than that which covers the fore part of the body ; the scapula, in addition to the ribs, protects the posterior part of the chest ; the spinal column lies along the whole length of the back ; and the bones of the pelvis have their whole breadth turned backward.

Falls are the more serious as they occur in a more perfect state of extension of the articulations : the falls of a child, whose limbs are in an habitual state of flexion, are much less dangerous than those of a strong and powerful adult, whose body falls in one piece, if I may be allowed that expression. The falls which skaiters meet with on the ice are often fatal, from fracture of the skull, which, placed at the extremity of a long lever formed by the whole body, whose articulations are on the stretch, strikes the slippery and solid ice with a momentum increased by the quickness of the fall.

We have already seen, that wading fowls remain a long whole standing, without effort, by means of a peculiar contrivance in the articulation of the tibia to the thigh bone ; but all other birds are obliged to employ muscular action when standing, except during sleep. The greater part, it is well known, roost on a branch, which they grasp firmly with their claws. Now this constriction, by which they cling to their support, is a necessary result of the manner in which the tendons of the flexors of their feet descend along their legs. These tendons pass behind the articulation of the heel ; and a muscle which arises from the pubis joins them, as it passes in front of the knee, so that the bird has but to give way to his weight, and the joints, becoming salient on the side along which the tendons run, stretch and pull them, and make them act upon the feet, so as to draw in the claws to clasp tightly the branch on which he is perched. Borelli was the first who understood distinctly, and explained satisfactorily, this phenomenon.†

CLXXXV.—Although standing on both feet is most natural to man, he is able to stand on one ; but the posture is fatiguing, from the forced inclination of the body to the side of the leg which supports him, and the effort of contraction required to keep up this lateral inflexion. The difficulty increases, if, instead of resting on the entire sole, we choose to stand on the heel or on the toe : the base of support is then so small, that no effort is sufficient to keep the centre of gravity long together, in the requisite situation.

As to the degree of separation of the feet, which gives the firmest possible stand, it depends upon their length. When they enclose a perfect square, that is, when taking their length at nine inches, each side of the quadrilateral

* This tendency is much less distinct in tall, slender men. It is observed that they, for the most part, stoop in walking, less from the habit of bending forward, than to prevent the centre of gravity from falling behind. Pregnant women, dropsical patients, all persons who have much embonpoint, throw their body back, from an opposite and easily understood reason.

† *De motu animalium*, Prop. 150. *Quæritur quarè aves stando, ramis arborum comprehensis, quiescunt et dormiunt absque ruinâ.* Tab. ii. fig. 7.

figure is of that measure, the stand is the firmest that can be conceived. Nevertheless, we are far from keeping or taking this posture to prevent falls. The wrestler who wants to throw his antagonist, strides much more; but then he loses on one side what he gains on another; and if he stride thirty-six inches on the transversal line, it will need much greater force to overthrow him on that side; but it will take much less to throw him forwards, or on his back. Wherefore, one of the great principles of this gymnastic art, is to bring back the feet to a moderate stride, in the line of the effort which is foreseen to require resistance.

There is some resemblance to standing in the attitudes of kneeling and sitting.

In the first, the weight of the body bears upon the knees, and we must bring back the body, to throw the centre of gravity over the middle of the legs. Accordingly, if we have nothing before us to lean on, this posture is extremely distressing, and we cannot long keep it on. I have said, in another work, that genuflexion rendered monks very liable to hernia; the abdominal viscera being pushed against the anterior and lower part of the abdomen, by the throwing back of the body.

In sitting, the weight of the body bearing on the tuberosities of the ischia, there is much less effort required than in standing on the feet. The base of support is much larger; and when the back leans, almost all the extensor muscles employed in standing are in action.

CLXXXVI. *Of the recumbent posture. Decubitus.*—All the authors who, like Borelli, have treated professedly of the animal mechanism; all the physiologists, who, like Haller, have set forth in some detail the mechanism of standing and of progression, have completely passed over the consideration of the human body in repose, left to its own weight, in lying on an horizontal plane. The intention of the following observations is to fill up this gap. Let us consider, at setting out, that lying on an horizontal plane is the only posture in which all the locomotive muscles recover the principle of their contractility, exhausted by exertion. Standing, without motion, has only the appearance of repose; and the unremitted contractions it requires, fatigue the muscular organs more than the alternate contractions by which the various motions of progression are carried into effect.

The human body, stretched on an horizontal plane, reposes in four positions—as it lies on the back, the belly, or one or other of the sides. The Latin tongue expresses the first two situations by the terms supine and prone.* It has no particular word for lying upon the side.†

Lying upon the right side is the most ordinary posture of sleep, in which we rest most pleasantly, and longest together. There are very few, except under constraint of some faulty organisation, who lie on the other side. This depends on two causes: when the body lies on the left side, the liver, a bulky viscus, very heavy, and ill steadied in the right hypochondrium, presses with all its weight on the stomach, and draws down the diaphragm; thence ensues an uneasiness, which hinders long continuance of sleep, or disturbs it with distressing dreams; then the human stomach presents a canal, in which the course of its contents is obliquely directed from above downwards, and from left to right: the right or pyloric orifice of the stomach is much less raised than its left or cardiac orifice. Lying on the right side favours, therefore, the descent of aliments, which, to pass into the intestines, are not obliged to ascend against their own weight, as they must in lying on the left

* Cubitus supinus, *Plin.* Cubitus pronus, *Cic.* Cubare in faciem, *Juven.* Supinus vel pronus jacere.

† Dextro vel lævo latere cubare; cubitus in latus. *Plin.*

side. These two anatomical causes exert their influence on the generality of men; and if there are any who fall into the habit of lying on the left, one may safely conjecture some vicious organisation, or some accidental cause, that determines them, as by instinct, to this posture.

Let us suppose an effusion of blood, water, or pus, in the sac of the pleura of the right side. The patient lies on this side, that the weight of his body may not oppose the dilatation of the sound side of the chest. The parietes of this cavity are not equally distant from its axis; the pressure of the body on the plane of support prevents the separation of the ribs, whether as a mechanical hindrance to the displacement of these bones, or in numbing the contractility of the muscles of inspiration, all being more or less compressed. Now, as the healthy lung must supply the place of the diseased, nothing could be more in the way than to produce, on that side, by a bad posture, a constraint equal to that occasioned by disease on the other.

It has long been imagined, and it is taught still, that in thoracic effusions, patients lie on the side of the effusion to hinder the effused fluid from pressing on the mediastinum, and pushing it against the opposite lung, of which it will constrain the developement. The following experiments shew clearly enough the error of such a supposition:—

I have several times produced artificial hydrothorax by injecting the chests of several bodies with water, through a wound in one of the sides. This experiment can be made only on bodies in which the lungs are free from adhesion to the parietes of the chest; and the number is smaller than might be imagined. You may introduce in this way from three to four pints of water. I afterwards opened carefully the opposite side of the chest: the ribs removed and the lung displaced, gave room to see distinctly the septum of the mediastinum stretched from the vertebral column to the sternum, and supporting, without yielding, the weight of the liquid, whatever might be the posture given to the body.

It is evidently for the sake, then, of not preventing the dilatation of the sound part of the respiratory apparatus, already condemned in one part to inaction, that patients in thoracic effusion lie constantly on the side of the effusion. It is for the same motive, to which we may add that of not increasing the pain by dragging downward the inflamed pleura, that patients in pleurisy lie on the affected side. The same thing happens in peripneumonies; in a word, in all diseased affections of the lungs and parietes of the chest.*

Lying on the back, which is unusual in health, is natural in many diseases. It commonly indicates more or less weakness of the muscles of inspiration. The contractile powers which perform the dilatation of the chest, when affected with adynamia, in fevers of a bad character, or after extreme fatigue, carry very imperfectly into effect this dilatation. Nevertheless, a determinate quantity of atmospherical air must be admitted every moment into the lungs, and the general weakness would be increased if respiration did not impregnate the blood with a sufficiency of oxygen: patients choose, therefore, the posture which makes the dilatation of the lungs easiest for their weakened muscles. The posterior parietes of the chest, on which the body reposes when lying upon the back, are almost useless in the expansion of the cavity. The ribs, which have the centre of their motions in their articulations with the vertebral column, are almost immovable backwards, and the movableness of these bones increases with the length of the lever which they represent; so that no where is it greater than at the anterior extremity terminating in

* This is not so remarkably the case until after adhesions of the pleuræ have taken place.—*J. C.*

the sternum. Thus lying on the back has the double advantage, of not constraining any of the muscles of inspiration, and of not opposing the motion of the ribs, except at that part where these bones have the least play. Lying on the back is one of the characteristic symptoms of putrid or adynamic fever, of scurvy, and of all diseases of which debility of the contractile parts forms the principal feature. After the fatigue of a long march, or of any other continued exertion, we take this position in lying, and change it only when sleep has sufficiently replaced the loss of contractility.

Lying on the belly has effects directly the reverse. The expansion of the chest is hindered exactly where the bony structure is formed for the greatest play of motion; the abdominal viscera are, besides, pushed up on the diaphragm, of which they resist the depression, and the posture is accordingly unusual. The continuance of it during sleep is possible only to the robust: others, even when they do fall asleep in this posture, soon awake, from troubled and distressing dreams, under the agony known by the name of the night-mare. We sometimes seek this posture to constrain respiration, and so abate inward excitation; in the heighth, for instance, of a febrile paroxysm.

The different postures of lying having reference to the degrees of facility of respiration, very young children, and persons advanced in years, prefer lying on the back, this posture being, as was already observed, the most favourable to the motions of respiration. Respiration, like all the other functions of the animal economy, with the exception of the circulation of the phenomena which immediately depend on it, requires a kind of cultivation: it is but feebly performed at an early period of life. It is only after a certain number of years, and when the muscles of respiration, at first small and weak, acquire strength from the very circumstance of being called into frequent action, that the chest dilates with facility, and that the lungs enjoy the full exercise of their faculties. Until that period the enlargement of the chest and the dilatation of the lungs took place in an imperfect manner, and the child was unable, even by spitting, to free itself of the mucus with which its bronchiæ are apt to get filled, and which render the pulmonary catarrh, called the hooping-cough, so dangerous at an early period of life. In like manner in an old man, the muscles debilitated, and returned to the relative weakness of infancy, in vain strive to clear the air-cells of the mucus with which they become obstructed in the suffocating catarrh. The mechanical process of respiration is, therefore, equally difficult in the child, from the weakness of the muscles which have remained in a long-continued state of inactivity; and in the old man, from the debility of the same organs, and from the induration of the cartilages. Thus, at those two distant periods of life it is most natural to lie on one's back, but there is a sufficiently remarkable difference in that respect, and which may now be inquired into.

In the foregoing observations I have always spoken of the human body as stretched on a perfectly horizontal plane. It is seldom, however, that we rest on such a surface; almost every one, and especially persons advanced in life, require that the plane should be inclined, and that the head should be raised to a certain degree, else the brain would become affected with a fatal congestion of blood. Children, on the other hand, suffer no inconvenience from a neglect of this precaution whether it is that in them the vital power has more energy, and thus balances better the laws of mechanics, by opposing more powerfully the effects of gravitation, or whether it is that in very young children the parietes of the arteries within the skull have a proportionate thickness, and consequently greater power. The extreme disproportion observable in adults between the cerebral arteries and those of other parts of the body, in the thickness of their parietes, is but trifling in children;

and may not this difference of structure, which I have several times observed in the course of dissection, be considered as one of the principal causes which in old age bring on apoplexy—a disease to which the child is not liable?

It is well known, that as the enlargement of the chest is produced by the depression of the diaphragm, persons who have taken a plentiful meal, dropsical patients, and pregnant women, cannot rest without lying on a very inclined plane, so that the chest being considerably raised, and the patient, as it were, seated, the weight of the abdominal viscera draws them towards the most depending part, that their bulk may not interfere with the depression of the diaphragm.

We might now inquire what is the posture in which the body rests with least fatigue. The investigation, unimportant to the physician, would be of the highest value to the arts which have for their object the imitation of nature. In consequence of ignorance on this subject, we often see, in the works of several of our sculptors, figures in attitudes of repose so incorrect and uneasy, that they could not maintain them without considerable effort and fatigue.

CLXXXVII. *Of the motions of progression. Of walking.*—Walking, running, and leaping, are so closely connected, that it is difficult to distinguish them. There is, in fact, very little difference between walking in a certain manner, or running; and running is most frequently produced by the complicated mechanism of running and leaping. In the most natural way of walking, we, in the first instance, poise the body on one foot; then, bending the opposite foot on the leg, the latter on the thigh, and the thigh on the pelvis, we shorten that extremity; we at the same time carry it forward, extend its articulations which were bent, and, when firmly applied to the ground, we bend the body forward, and carry back the centre of gravity in that direction; and, performing the same motions with the limb which remained behind, we measure the space more rapidly, *cæteris paribus*, as the levers on which the centre of gravity alternately bears are longer. The weight of the body, compared to that of the lower extremities, is as that of a carriage which moves, in succession, on the different spokes of its wheels.

The centre of gravity does not move along a straight line, but between two parallels, in which space it describes oblique lines from the one parallel to the other, and forms *zig-zags*. The oblique direction of the neck of the thigh-bones accounts for the lateral oscillations of the body when we walk; the arms, which move in a different direction from that of the lower extremities, serve to balance us, preserve the equilibrium, and correct the staggering, which would be much greater if the neck of the thigh-bone, instead of being oblique, had been horizontal. The impulses communicated to the trunk are reciprocally balanced, and the latter moves in the diagonal of a parallelogram, whose sides are represented by the line of these impulses. We constantly deviate from the straight line in walking; and if the sight did not enable us to see, at a distance, the object towards which we are moving, we should go widely from it. If you place a man, with his eyes blindfolded, in the middle of a square field, he will, in his attempt to get out, and thinking that he is moving in a straight line, make for one of the corners. It is, almost always, towards the left that we deviate, the right lower extremity, which is the stronger, inclining the body towards the opposite side. Those who are lame depart much more from a straight line, and deviate towards the side of the shorter leg. The motions which they are obliged to use, and which render their gait so remarkable, are occasioned by the necessity of incessant and powerful efforts to prevent the body from giving way to

its own weight, and to the greater power of the sound extremity, which inclines it towards the affected side.

The breadth of the feet, and a moderate separation of these parts, give a much firmer support to the centre of gravity. Thus, in walking on a moving and insecure surface, we hold apart our feet, so as to include a greater base of sustentation. Those who have long been at sea, acquire such a habit of holding their feet asunder, in the way they are obliged to do during the rolling of a ship, that they cannot lose the habit even when on shore, and are easily recognised by their gait. A sailor is unfit for active service till he has acquired what is called by seafaring people a seaman's foot, that is, till he is capable of stepping firmly on the deck of a vessel tossed by the tempest.

The gait of a woman, from her having smaller feet, is less firm; but ought we, from that circumstance, to infer, with the most eloquent writer of the eighteenth century, that this diminutive size of the foot is connected with the necessity of her being overtaken in flight? The concave form of the sole of the feet, by enabling them better to adapt themselves to the unevenness of the soil, concurs in giving a firmer footing in walking, and in other motions of progression. There is, in walking, an intermediate moment, between the beginning and end of a step, during which the centre of gravity is in the air: this lasts from the moment when the centre of gravity is no longer in the foot which remains behind, till it returns into the other foot which is carried forward.

Walking is modified according as it takes place on an horizontal or an inclined plane; in the latter case we ascend or descend, and the exertion is much more fatiguing. To explain the action of ascending, let us suppose a man at the bottom of a flight of stairs, which he wishes to go up; he begins by bending the articulations of the limb which he is desirous of carrying forward; he raises it thus, and shortens it to advance; and when the foot, which is in a state of semi-extension, rests on the ground, he extends the articulations of the other extremity, carries thus the body upward in a vertical direction, and completes this first step by contracting the extensors of the leg that were first in action, so that they may bring forward and restore to it the centre of gravity, to which the posterior leg, whose foot is extended, has given a vertical motion of elevation. Hence, in ascending, the calves of the legs and knees, especially the latter, are so much fatigued; for the effort with which the extensors of the foremost leg bring back again upon it the centre of gravity, is more powerful than that by which the gemelli and the soleus impart to it, by extending the hindmost foot, a motion of vertical elevation.

To relieve the extensors of the leg, we bend the body forward as much as possible; we lean back, on the contrary, in descending a flight of stairs, or a rapid slope, in order to slacken the motion by which the body, yielding to its own weight, falls on the leg that is carried forward.

At the moment when the centre of gravity is no longer within the base of sustentation, all the powers unite in action, that it may fall as little as possible from a vertical direction. The glutæi steady the pelvis and straighten the thigh, and the lumbar muscles extend the trunk on the pelvis; hence, in going down a slope, the loins get so much fatigued. We are less fatigued in going down hill, when the slope is moderate, than in going up hill, as the force of gravitation, or the weight of the body, assists considerably the descending vertical motion. The motion of walking, when we take very long steps, resembles that of going up hill, as the body being lowered every time

the legs are much apart, requires to be elevated at each step towards the foremost leg.

At every step we take, the articulation of the leg with the foot is the principal seat of an effort, to which physiologists have not paid any attention. The whole weight of the body is supported by the action of the levator muscles of the heel, and the astragalus supports this weight, which varies according to the corpulence of the person and the burthen with which he is loaded. The weight of an adult, of common stature and of moderate size, may be estimated at about 150 pounds, but which sometimes, in corpulent people, amounts to between 4 and 500 pounds. If, then, to the weight of the body there be added that of the burthens which it may support, it will be conceived how immense the efforts must be which are, as it were unconsciously, carried on in the articulation of the foot with the leg. But how numerous the resources which nature has provided to overcome this great resistance! how many the circumstances she has happily combined to accomplish this without fatigue! In the first place, the foot in this action represents a lever of the second class, and this lever, it is well known, is the most advantageous, the resistance being always nearer to the fulcrum than the power, and the arm, by which the latter acts, consisting of the whole length of the lever. If you attend to the mechanism of the different parts of the skeleton, you will no where find so powerful a lever applied in so favourable a manner. The os calcis, by carrying the foot beyond its articulation with the leg, adds likewise to the length of the lever by which the power acts. Its length has considerable influence on our strength, on our power of taking, without fatigue, long walks, or engaging in exertions requiring considerable muscular force in the lower extremities. The negroes, who excel in running, in dancing, and in all gymnastic exercises, have a longer and more projecting heel than Europeans. They dance best whose tendo Achillis is most detached, that is to say, projecting, and at the greatest distance from the axis of the leg; which implies that its lower attachment is carried back by the prolongation of the os calcis.

Those who have a short heel have a long and flat foot: this conformation, which when marked is faulty, is not only unfavourable to beauty of form, but is, besides, remarkably injurious to the strength of the limb as well as to freedom of motion. Men with flat feet are always bad walkers; hence this flattened form, when very considerable, is viewed as unfitting a man for military service. Lastly, the term denoting this physical imperfection (*pieds plats*) is accounted insulting in the French language, as well as in several others. But let us go on with our inquiry into the advantageous disposition of the articulation of the foot with the leg, for facility in walking, and in the different motions of progression.

We have seen that the tendons are generally inserted at a very acute angle into the bones on which they act: in the present instance, however, the insertion takes place at a right angle; the common tendon of the muscles of the calf of the leg joining the os calcis at the angle most favourable to their freedom of action. With the exception of the muscles which move the head and lower jaw, no others are so evidently disposed with this purpose. Nature has not been contented with forming the foot in such a manner as to afford the most advantageous lever, to which the moving powers are applied, at the greatest possible distance from the fulcrum, and at the angle most favourable to their action; she has further increased the efficacy of this action, by adding extraordinarily to the number of muscular fibres. There is not in the body a stronger muscle than the soleus, whose short and oblique fibres between the two wide aponeuroses which cover its anterior and pos-

terior surfaces, are more numerous than in any other muscle, as may be conceived by considering the extensive surfaces to which they are attached. Besides, the tendo Achillis is kept in a due degree of straightness by the aponeurosis of the leg behind it.

Every thing in the powers, as well as in the levers, is formed so as to overcome the resistance without difficulty; that is, so as to raise the weight of the body by the extension of the foot, the end of which rests on the ground, in every motion of progression.

This immense power with which the muscles of the calf of the leg act to raise the heel, and to support the whole weight of the body resting on the astragalus, accounts for the possibility of transverse fractures of the os calcis, and for the rupture of the tendo Achillis, notwithstanding its great thickness; and should lead one not to allow patients, after such accidents, to walk freely for several months, the substance which unites the parts being liable to rupture, as is known to have been the case in several instances. This same arrangement of parts likewise accounts for an accident, which physiologists have long endeavoured to explain by a very unsatisfactory theory.

It not unfrequently happens that the mere effort of walking occasions a rupture of some of the fibres of the gemelli and of the soleus, in consequence of which there comes on pain, attended with induration of the muscles, and with a certain degree of ecchymosis, occasioned by the extravasation of blood. Pathologists suppose these symptoms to depend on a rupture of the plantaris muscle: this rupture, however, is hypothetical, has never been proved by experience to exist, and its supposed symptoms are altogether idle and fallacious.

I could, if it were not out of place, bring forward several cases of this affection: in all the cases which have come under my own observation, the use of the bath, of emollient and slightly narcotic poultices, but, above all, continued rest, while the symptoms lasted, have appeared to me the most appropriate remedies.

CLXXXVIII. *Of running.*—In running, the foot that is hindmost being raised before that which is foremost being firmly applied to the ground, the centre of gravity is for a moment suspended, and moves in the air, impelled by the force of projection, the action of which principally constitutes leaping.

The mechanism of running is a compound of that of walking and leaping, but resembling most the latter; hence some authors have defined it to consist of a succession of low leaps. The steps are not longer than in walking, but merely succeed each other with greater velocity. The centre of gravity is transferred with more rapidity from one leg to the other, and falls are much more apt to take place. The quick repetition of the same motions in running requires a very lively contractility in the muscles which move the extremities; and as the energy of this vital property is proportioned to the extent of respiration, and to the quantity of air which the blood acquires in passing through the lungs, in running we pant and breathe frequently, and at short intervals, without any particular enlargement of the chest at each act of respiration. It was necessary that the parietes of this cavity should, in running, be remarkably fixed; for it becomes the point on which those muscles are inserted which steady the pelvis and loins, and prevent their yielding an unsteady basis to the lower extremities. The best runners are those who have the strongest lungs, that is, who can give to the chest the greatest degree of permanent dilatation. In contending for the prize in running, you may see them throw back their head and shoulders, not only to obviate the propensity which there is in the line of the centre of gravity to fall towards the anterior plane, but likewise that the cervical column, the scapulæ, the

clavicles, and the humerus, being fixed, may furnish a firm attachment to the auxiliary muscles of respiration.

We should run with much less speed if we applied to the ground the whole sole of the foot, partly from the time which would be taken up in thus applying the foot to the ground, and partly by the friction which would necessarily take place. Hence in running we generally touch the ground only with the end of the foot. We run with most speed when the foot is in a state of extension, the leg being moved rapidly by the extensors of the knee. This accounts for the tendency which there is to fall while we run, the centre of gravity obeying impulses which follow each other in rapid succession, and never resting but on a basis of very limited extent. Another reason why the slightest unevenness of the ground is apt to occasion falls in running is, that the rapid motion communicated to the body by the sudden and perpetually recurring extensions of the posterior extremity, increases at every step, so that it is impossible to stop suddenly, and without having previously slackened one's pace, and moderated the impulse to which the body is subjected.

As it is mostly forward that falls are apt to take place, in running we always throw back the head, and make use of our arms to balance the body, so that they may be in constant opposition to the legs; that is, that the right lower extremity, for example, being carried forward, the left arm may be balanced backward.

Few animals are better formed than man to run with speed: his lower limbs are in length equal to one-half of the whole length of the body, and the muscles which move them are very powerful: hence savages, who are in the constant habit of running, overtake the animals which they make their prey; and even in Europe there are professed runners who equal in swiftness the fleetest horse. This animal, like every other swift quadruped, would move much more slowly than man, on account of the number of the limbs on which he rests, if he had not the power of moving them in pairs, and thus reducing his legs to two, as in what is called full gallop.

CLXXXIX. *Of leaping.*—Leaping, in man, is performed principally by the sudden extension of the lower limbs, whose articulations were in a previous state of flexion. The alternate angles of the foot, of the knee, and hip, disappear, and the extensors contract in almost a convulsive manner. This straightening is not limited to the lower limbs in violent leaping; it likewise affects the vertebral column, which acts as a bow in unbending. Professor Barthéz, who has the merit of having suggested this explanation, which Borelli and Mayow had very imperfectly understood, perhaps goes too far in considering as imaginary a power of repulsion in the ground. This re-action, admitted by Hamberger and by Haller, clearly operates when we leap on an elastic floor; it enables tumblers to rise, without much effort, on the rope which bears them. But though all physiologists do not admit that in leaping there is a re-action from the ground, it is universally admitted that there must be a certain resistance from the ground on which we tread. In fact a moving sand, yielding to the pressure of the body, would, by giving way to a considerable degree, render it impossible to leap. The instantaneous contraction of the extensor muscles is so powerful in extending the lower extremities, and in communicating to the body a power of projection, so as to raise it, that frequently during this effort the tendons of these muscles, or even the bones into which they are inserted, break across. It is on this account that dancers are very apt to fracture their patella. This accident happens at the moment when their body, in rising from the ground, is powerfully elevated to a certain height.

If leaping consists merely in the sudden straightening of the lower extremities, whose articulations are bent in alternate directions, it must be more considerable according as these are longer, more bent on one another, and as the muscles which straighten them contract more powerfully. Hence animals that move by leaps, as the hare, the squirrel, and the jerboa, have posterior extremities of considerable length in proportion to their fore legs. Their different parts are, besides, capable of considerable flexion. All these animals, strictly speaking, are incapable of walking or running, and they move by leaps or bounds succeeding each other with different degrees of rapidity. Some, however, as the rabbit and the hare, are capable of running when climbing up a steep place, as the slope in this case lessens the effect of the impulse communicated by the extension of the posterior limbs; an impulse which, from the strength and length of these extremities, throws the whole weight of the body on the fore legs, which are weaker and shorter, with such a degree of force, that the animal is obliged to stiffen these and to keep them straightened, and in a state of extension, to avoid striking the ground with his head while leaping on an horizontal plane. Frogs, but especially grasshoppers and fleas, between whose hind extremities and the rest of the body there is the greatest disproportion, astonish us by the very considerable space which they can clear at a leap; but the wonder ceases, when we consider that powers communicate to the masses equal degrees of velocity, when proportionate to one another: now, the space gone over depending entirely on the velocity, since the body that leaps loses, by a gradation which nothing can lessen, that which it had acquired, these motions must be nearly alike in small and in large animals.

Swammerdam says, that the height to which grasshoppers rise in leaping is to the length of their body as 200 to 1. A flea leaps still farther and more swiftly.*

The larva called the cheese maggot forms itself into a circle by contracting, as much as possible, its abdominal muscular fibres: after having, in this manner, brought near to each other its head and tail, it suddenly extends and straightens itself, and thus springs forward a considerable distance. It is by a similar mechanism that the salmon, the trout, and other fishes, swim against rapid currents interrupted by waterfalls. They bend their body to a considerable degree, straighten it powerfully, and thus overcome the obstacle which opposes their progress. I believe, however, that in this particular case the leap is not effected solely by the straightening of the elastic curve, as is maintained by some authors, but that it is likewise occasioned by the resistance against the water of the tail of the fish, which strikes it powerfully at the moment of raising itself; in the same manner as, in the northern seas, the enormous whale strikes with so sudden and violent a blow of her tail against the water, as to receive from it a fixed point, and rise to the height of fifteen or twenty feet, as we are informed by navigators. Lobsters leap by violently extending their tail—an elastic and contractile arch, which they had previously kept bent under their body.

This theory of leaping would seem to be contradicted by what is related by Professor Dumas, of a man without thighs, and who, nevertheless, performed surprising feats of dexterity and agility. But in this instance might not the pelvis, the vertebral column, and especially the lumbar portion of the latter,

* Barthéz states, in his work on mechanics, that the Arabs call this little insect the father of leaping; and that Roberval, a natural philosopher of considerable merit, had written a work entitled *De Saltu Pulicis*. Such a subject, thought by the ignorant to supply matter only for idle and fruitless speculation, may furnish results highly interesting, when treated by an able man. *In tenui labor.*

make up, by a greater mobility, for the want of the longest of the three levers formed by the lower extremity ?

In the act of leaping, the body, which has received the impulse, may rise in one or two ways perpendicularly to the horizon, which constitutes the vertical leap, or in a direction more or less oblique. The vertical leap is always of less extent than that which takes place in an inclined direction, and the latter is always greater when it has been preceded by running. In running before leaping we have already acquired an impulse which is added to that which the mechanism of leaping may produce.

To convince ourselves of the reality of this additional power, let us recollect how difficult it is to stop suddenly in the midst of a race, if we have not previously slackened our pace. This impulse is one of the causes which makes runners fall forward when the slightest obstacle meets their feet; but whatever may be the force, the direction of leaping, and the powers which produce it, the body by which it is executed must be considered as a real projectile, that is impelled by a motion counteracted by the force of gravitation. Whatever motions we may perform, every thing depends on the first impulse; as soon as the feet cease to be in contact with the plane which supports them, it is no longer in our power to augment the force of the leap, or its swiftness. In dancing, it is impossible to excel in cutting capers, unless one is capable of rising to a certain height. I have uniformly observed, that in the most celebrated public dancers the trunk, and especially the lower limbs, are very muscular; the calf of the leg, the buttocks, and the back, indicate, by their bulk, a remarkable degree of energy in the extensors, by whose action leaping is chiefly effected.

A dancer who rises vertically, falls back to the ground when the force of gravitation exceeds the impulse which he had received: his fall resembles that of a projectile in vertical motion; it takes place according to a descending line that is perfectly similar in direction and height to the ascending line.

The same thing takes place in the oblique leap, except, however, that the body, like a shell projected by the explosion of gunpowder, describes a parabolic curve, ascending as long as the impelling power exceeds the force of gravitation; descending, when the latter, which increases during the progress of the leap, is equal to the force of the impulse. This takes place when the body has described a curve which represents the half of a parabola: from that moment the force of gravitation goes on increasing, and the body descends in a curve corresponding to the first.*

CXC. *Of swimming.*—Few animals have more difficulty than man in supporting themselves on the surface of a fluid; yet the weight of the human body exceeds but little that of the same bulk of water; sometimes, even when the body is loaded with much fat, its specific gravity and that of water are the same. Hence it is observed, that corpulent men swim with less effort, but the weight is not equally distributed over every point of the supporting fluid. The head, whose relative weight is very considerable, is the principal difficulty in swimming, and it requires some effort to keep it raised so as to allow the air to enter freely into the lungs through the mouth and nostrils. The upper and lower limbs act alternately against the water, which they displace by pressing on it. In these various motions there is a successive flexion, extension, abduction, and adduction of the limbs: most of the muscles of the body are in motion, and have their fixed point of action in the chest, which swimmers keep expanded by retaining, by a constriction of the glottis, a considerable quantity of air within the pulmonary tissue. This continuous dila-

* *In saltu ad horizontem obliquo, motus fit per lineam parabolicam proximè.*—BORELLI *Op. cit. Prop.* 178.—Vid. Galileo on the motion of projectiles.

tation of the chest is attended with this further advantage, that it renders the body specifically lighter. The force with which the swimmer is obliged to strike the water, the rapidity with which the motions must succeed each other, that the fluid may yield him a sufficiently fixed point of action, accounts for the fatigue with which this exertion is attended.

Fishes are adapted, by their structure, to the element in which they live—the form of their body, bounded every where by salient angles, is well calculated to separate the columns of a fluid. A bladder filled with azote, which is expelled at pleasure, renders their specific gravity less than that of water, according to the quantity of gas it contains; lastly, their tail, moved by powerful muscles, may be considered as an oar of great strength, the motions of which impel the fish forward, while the fins, like so many secondary oars, facilitate and direct his motions.

The air-bladder of fishes gives to their back a sufficient degree of lightness to enable it to remain upward, else this part of the body, which is the heaviest, would draw after it the rest, and the animal, lying on his back, would be incapable of performing any motions of progression: this happens when this bladder is burst or punctured. Constrictor muscles expel the gas which it contains, and force it into the stomach, or œsophagus, when the animal wishes to sink. This expulsion becomes impracticable, if the gas undergoes considerable expansion from the application of heat, and resists the compression that is applied to it. Hence, during the fry-time, fishes, after remaining long on the surface of the water, exposed to the heat of the sun, become unable to sink, and are easily caught.*

As the fish is entirely surrounded by a medium which presents on every side an equal resistance, the velocity which he might have acquired, by striking the fluid behind with his tail, would be lost, from the resistance of the water which he would have to displace forward, if, immediately after striking with his tail, he did not bring it back into a straight line, so as to present to the fluid only the inconsiderable breadth of his body: the velocity with which he moves is, besides, very inferior to that with which he uses his tail. This part being brought into a straight line, the fish contracts it to its smallest dimensions, at the same time that he brings it to the other side; he then expands it and strikes the fluid in a contrary direction, in a line between the two oblique impulses which both strokes have given to it. The fish turns horizontally, and directs himself towards the side he chooses, by striking more powerfully, or with greater quickness, on one side than on the other, or by striking only on one side.

Fishes without an air-bladder are reduced to live at the bottom of the water, unless they have a flat body, and are furnished with horizontal fins, so as to enable them to strike a considerable surface of water, in a powerful manner, as is the case with rays, whose wide fins are not inaptly termed wings; the motion of these fishes in the water precisely resembling that of birds in the air, with no other difference but that of the different density of the medium in which they move, as will be shewn in treating of the motions of progression peculiar to this class of animals.

CXCI. *Of flying.*—A bird, in rising or in moving in the air, has to use much more force, and with much greater velocity, than a fish in swimming.

* The nature of the air contained in the air-bag of fishes was investigated by Priestley and Fourcroy, and lately by M. Biot. According to the accurate and extended experiments of the last-named inquirer, it would appear to consist entirely of oxygen and azote. The proportion of these gases vary according to the species of fish and depth at which they are caught; that of oxygen increasing with the depth of water, from an almost insensible quantity until it amounts to 87 parts in a 100 of the whole air. It would appear, from the experiments of M. Biot, that this air is a secretion from the sac which contains it.—*J. C.*

He has not the power, like the latter, of placing himself *in equilibrio* with the fluid in which he moves, by means of an internal organ that renders his specific gravity equal to that of the medium he is in. This medium, besides, presents less resistance to the powers which strike it to obtain a point of support.

Though birds are incapable of becoming as light as the air, it is, however, in their power to obtain a specific gravity not much exceeding that of the atmosphere. Nature has rendered them very light by providing them with very capacious lungs, capable of great dilatation, from the remarkable mobility of the parietes of the chest, and by extending the lungs into the abdomen, by means of membranous sacs, and into the skeleton by means of canals, which establish a communication of these abdominal and osseous aerial tubes with the pulmonary organ; so that the whole body, distended by air rarefied by a considerable degree of heat, since it is ten degrees above that of other warm-blooded animals, clothed in feathers almost as light as the air itself, requires but a moderate degree of force to support itself in that medium. On the other hand, when the wings are expanded, they present to the fluid a very extensive surface: the pectoral muscles which set them in motion are, besides, sufficiently strong to strike the air with a power, and to repeat the stroke with a rapidity and continuousness of which no other animal would be capable. We know how powerful* the muscles of the wings are, even in the tame fowl, which make so very little use of them. Lastly, the contractility of these very powerful muscles is greater in birds than in any other animal: no one possesses so much strength in so small a compass. What quadruped, of the same weight as an eagle, could strike with his foot so violent a blow as that bird, when, to stun his prey or to defend himself, he gives repeated blows with his pinion? This muscular energy is, no doubt, connected with the extensive respiratory organs, and with the highly stimulating qualities of a blood that is warmer, more oxidised, more concrescible, in a word, more arterialised, than that of any other animal.

Let us now inquire how birds, endowed with an organisation so favourable to flying, perform that action. A bird begins by ascending into the air, either by rising at once from the ground, or by allowing himself to fall from a height. If on the ground, and if his wings are too large to be freely spread, he has a difficulty in rising: in that case he goes to an elevated spot and throws himself from it, that he may have sufficient room to extend his wings and strike in the air the first stroke that is to raise him. The wings expand horizontally, the humerus, which forms their principal part, standing off from the body; they then descend rapidly, and as the air resists the sudden effort which tends to depress it, the body of the bird is elevated by a kind of elastic re-action, corresponding to the leap of man, and to the swimming of fishes; the impulse being given, the bird closes his wings, and contracts his dimensions as much as possible, that the impulse may be almost entirely employed in raising his body, and may not be counteracted by the resistance of the air. This resistance of the air, but particularly the weight of the bird, would soon overcome the velocity

* Birds have three pectoral muscles: the third, or *lesser pectoral*, is destined to draw the humerus towards the body; the *great pectoral*, which is attached to their enormous sternum, and alone exceeds in weight all the other muscles of the bird together; and the *middle pectoral*, whose tendon turns over a kind of pulley, and is attached to the head of the humerus, which it raises. By means of this mechanism, Nature has placed an elevator muscle at the lower part of the body, so as to increase the weight of this part of the bird, which, without this kind of ballast, might have been upset in the air. By these and other peculiarities in the organisation of flying animals, the centre of gravity is always below the insertion of the wings, and near that point on which the body is, during flight, suspended. The positions, also, assumed by the head and feet, are often calculated to facilitate flight, and to give to the wings every assistance in continuing progressive motion.—*J. C.*

that has been obtained, and he would drop, if, by again striking the air, he did not again rise. If the bird strikes a second time with his wings, before the impulse communicated by the first stroke is over, he rises rapidly, but, on the contrary, descends, if this motion is delayed. If he allow himself to fall only to the height whence he began to rise, he may, by a continuance of equal vibrations, keep at the same height. A bird sometimes ceases altogether to move his wings, closes them against his sides, and falls with a precipitate motion, like any other weighty body. The name of pouncing is given to the rapid descent of predacious birds on their prey. Observe a falcon drop suddenly on a poultry-yard: if, on the point of reaching the ground he perceives danger, he immediately spreads his wings, and thus saves himself from falling; for, whatever velocity he may have acquired in this rapid motion, the resistance of the air always increases as the squares of the velocity: he then rises anew and takes to flight. This peculiar act is called *resource.*

The oblique motions differ from the vertical motion which has just been described, in this, that the bird rises by a series of curves, which are more or less extended as the motion is more horizontal or vertical. In consequence of the peculiar strength of their wings, birds of prey have a very powerful horizontal motion, so that in soaring, the curves which they describe are so slight that the motion seems quite horizontal.

Swimming, to many birds, is a more natural mode of progression than flying: these birds are very light, their body is covered with a light down, and with feathers, over which the water glides very readily; their body is flattened, and rests on the fluid by a broad surface; their pelvis is shaped like the keel of a ship; lastly, their toes, united by webs, strike the water with a very broad surface. This is the case with the numerous tribes of web-footed or water-fowl.*

They who have conceived it to be possible for man to support himself in the air, by rendering his body specifically lighter, have not considered that it is impossible to give to the muscles which move the arms a sufficient degree of strength to enable them to move the machines which are adapted to them; and all who have ventured to try such machines have suffered for their rashness.

CXCII. *Of crawling.*—All the motions of progression, of which man and animals are capable, may be referred to the theory of the lever of the third kind. The body, in leaping as in walking, may be compared to an elastic curve, since the point of support, or fulcrum, is in the ground; the force, the spring or power, in the extensor muscles; and the resistance in the weight of the body. What is running but a succession of short leaps? and is not its mechanism intermediate between walking and leaping? Are not flying and swimming real leaps, in which the body of the animal alternately bends and unbends, having its support on media of much less resistance than the ground, on which walking, running, or leaping, are generally performed? The mode of progression peculiar to serpents and soft reptiles furnishes an additional application of the lever of the theory of the third kind. The snake, which moves by forming with its body horizontal and vertical undulations, assumes, in the course of its length, a series of curves and straight lines in succession, from the head towards the tail; but sometimes likewise from the tail towards the head, in the serpents called *amphisbœnous*, in which the scales covering the belly are equally favourable to a retrograde motion as to a motion forward.

The crawling of serpents is facilitated by the length of their body, by the

* The faculty of diving, &c. into a denser medium, possessed by some aquatic birds, is exerted in the same manner as that of flying in the air. Swimming on the surface of the water is performed entirely by means of the webbed feet of this class of birds.—*J. C.*

smoothness of their scales, the immense power of their muscles, and the flexibility of their vertebral column. The bones which form this part of the skeleton are articulated by arthrodia, and loosely jointed, so that a very slight cause destroys their union ; hence, a blow with a very small stick is capable of killing the largest serpents, if applied on the back. The lateral inflexions of this column are very considerable ; the degree of extension is limited by the spinous processes, and these are sometimes of considerable size, as in the rattlesnake. Hence, notwithstanding what has been stated by several authors, and although painters have represented serpents moving in vertical curves, they move, in most instances, in horizontal curves.

A serpent, to swim, is obliged to bend and unbend his body in more rapid succession : this swimming consists merely in crawling faster, and in moving on a less resisting plane.

The motions of reptiles in swimming surpass in strength and velocity those of reptiles which crawl on the ground, inasmuch as the latter yields a more fixed point than water. If the serpent is desirous of leaping, he suddenly, and at once, brings to a straight line all his curves, resting at the same time on the extremity of that which is nearest his tail ; then, as I have several times observed, he describes the smallest possible number of curves, bends into three or four greater arches than usual, but never into a single one, whatever the length of his body may be.

Tortoises, frogs, lizards, salamanders, and all reptiles that have legs, drag themselves along on their belly, being ill supported by their weak limbs, which bear no proportion to the bulk of their body, and they can scarcely be said to crawl by a mechanism similar to that which has just been explained.

Caterpillars and maggots crawl much in the same manner as serpents. The legs of the caterpillar, too feeble to support it, or, of themselves, to carry the body forward, are used by these creatures to obtain a hold on the surface on which they move, by bending in arches, mostly vertical, the parts situated between the legs, that are in pairs, at a certain distance from one another. The caterpillars that have a scaly covering crawl better, the elasticity of their scales assisting the contractile action of their muscular fibres. Earthworms move at times in undulations as the snake, and at others by dragging themselves like slugs. This last variety of crawling is performed as follows : instead of forming distinct curves, the contractile fibres of the reptile shorten themselves from the head, which is fixed, towards the tail, which is movable, and the animal performs only slight inflexions. We may compare the mode of crawling peculiar to some animals, to the motions by which a man lying horizontally on his belly, moves forward, by drawing his whole body towards his arms, which are in a state of extension, and with which he has a hold of some fixed object. The motion of the snail is performed almost entirely in the same manner.

The snail, loaded with his shell, adheres to the surface on which he moves by a viscid and glutinous fluid, which coagulates, and forms on his track a shining varnish. This creature fixes itself likewise on the ground by forming a vacuum with the part of its body on which it crawls, which is broad, fringed, and well adapted to answer the purpose of a cupping-glass. It is by this double resource of a viscid and glutinous fluid, and of a contractile exhauster, that the snail fixes the fore part of the body, and then draws towards this fixed part the rest of his body, loaded with the shell. This part of the snail, by which it fastens itself to the ground on which it crawls, bears some analogy to the tentacula which assist the progression of the sepia and other cephalopodous mollusca.

CXCIII. *Partial motions performed by the upper extremities.*—These motions will furnish us additional illustrations of the elastic curve, or of the third lever, to the theory of which may be referred almost all the motions of man, and of the lower animals. This idea simplifies and facilitates in a remarkable manner the study of animal mechanics ; it may be considered as a general formula, by the help of which we may obtain a solution of all the problems of this interesting part of physical science. Its application particularly distinguishes what has just been stated on motion, from what has been heretofore written on the same subject.

The upper extremities in man are not employed in motions of progression, at least not generally, except in a few instances, as, for example, when the limbs being extended and the hands having a firm hold of a body, the action of the great pectorals draws the whole body, lying prone on a horizontal surface, or suspended.

We experience a difficulty in climbing, because our hands alone enable us to grasp the body on which this mode of progression is to be effected, while the four extremities of the quadrumana and the sharp claws of cats, and those of climbing birds, render this action easy and natural to all these animals.

There exists so great a disproportion in point of length and strength between our upper and lower extremities, that walking on all fours can never be natural to the human species ; besides, as Daubenton observed, the situation of the foramen magnum of the occipital bone in man renders this attitude exceedingly uneasy. Its situation, near the centre of the base of the skull, and nearly horizontal, prevents the head from being raised sufficiently high to enable us to turn our face forward and to see before us ; and if we bring the head downward, it strikes the ground with its summit or with the forehead.* But our upper or thoracic limbs, though of no use in conveying us whither our wants require, are almost exclusively destined to perform motions by which we act on the objects towards which we have brought ourselves.

If we wish to push, or to draw towards us, or to propel afar, a movable body, to compress, to elevate, or to lower it, our upper extremities are almost exclusively engaged in this office.

In *pushing*, man places himself between the obstacle and the ground ; he bends his body between these two points, by bringing all his limbs into a state of flexion ; he then extends them ; his whole body represents a spring which is released and recovers itself, and the two extremities of which, meeting two obstacles, the ground and the body to which the impulse is to be communicated, exert their action on the one of the two which is the more easily moved. The force is equal to the contraction of the extensors, which elongate the body, previously in a state of decurtation, and advance the movable obstacle by the whole difference, in regard to length, of a man, whose limbs are in a state of flexion, and of the same man while these parts are in a state of extension. It is in the same manner, and by a similar mechanism, that, by pushing against the shore with an oar, we force a boat from it. The vertebral column represents an elastic curve, that straightens itself between the feet, which rest against the bottom of the boat, and the end of the pole or oar, pushed against the shore or the bottom of the water.

If, on the contrary, we wish to draw towards us a body, we seize it with extended arms ; we then bend them forcibly : the spring, that is in a state of tension, shortens itself, the effort is wholly performed by the flexors ; it

* Dictionnaire d'Histoire Naturelle de l'Encyclopédie Méthodique. Introduction, page 21 et suiv.

is less fixed, and of less duration than that of the extensors, because the axes of the bones do not correspond to one another in a straight line, and because the action is generally partial.

We can throw to a distance a projectile, the arm remaining pendulous, and performing a mere oscillatory motion, or by a whirling motion of the arm. This last action is much more powerful, because the muscles which go from the trunk to the upper extremity concur in it. In the former, the previous oscillations give to the arm a motion which is peculiar to it, added to the force of muscular contraction, and which augments the effect.

Professor Barthéz was aware that the motions by which the upper extremity stiffens itself, and assumes a state of extension, to project a movable body, or to repel a resistance that is opposed to it, perfectly resemble leaping, and are attended, like that action, with a sudden extension of the joints which were previously bent. In motions applied to a resistance that cannot be overcome, the body is not repelled with the force communicated to it in leaping, by the abrupt extension of the lower extremities. The scapula is too movable on the trunk, its articulation with the humerus is too unsteady, and the action of this bone is not directed, with regard to the shoulder, in a sufficiently favourable manner, to render the impulse equally great, even though the powers should be equal,—and they are far from being so. In every repulsion and in every attraction, whether we bring towards us an object or remove it from us, by acting upon it with our superior extremities, these limbs represent an elastic arch, which is curved or straightened by the action of its flexors or extensors; and these motions, like the greater number of those which we have hitherto considered, present a precise application of the levers of the third kind.

The action of seizing a body with the hand, is facilitated, 1st, by the action of the radius on the ulna, which performs pronation and supination, motions which belong exclusively to the hands, and of which the feet are incapable; 2dly, by the mobility of the wrist, which, properly speaking, is capable of flexion and extension in two directions; for the extension of the hand does not consist in merely bringing it intó a parallel line with the axis of the limb, but it is, besides, capable of turning it round towards the back part of the fore-arm,—a phenomenon not observable in any other articulation; 3dly, by the obscure motions on one another of the bones of the carpus, by which the palm of the hand becomes more concave; 4thly, by the motions of opposition and circumduction of the thumb and little finger; 5thly, by the great number of the phalanges: every thing in this part of the upper extremity proves the excellence of its structure, and justifies all that philosophers and naturalists have said of its advantages.

In applying pressure, for instance in pressing on a seal, nearly the whole weight of the body bears on one of the upper extremities, which is powerfully extended, the shoulder resting on the arm, so that the glenoid cavity of the scapula may be perpendicular to the head of the humerus.

It would be a superfluous task to endeavour to describe all the motions which our parts may execute: these partial motions are explained in anatomical works, in treating of the muscles on whose action they depend. I shall content myself with having inquired into the principal phenomena of animal mechanism, chiefly with a reference to the human structure. Fuller details on animal mechanism would be out of place in a work like this. They will be found in those works which treat professedly* of this important

* Consult J. A. Borelli *de Motu Animalium*, 4to. The errors contained in this work depend on the circumstance of the author's being more of a mathematician than of an anatomist. P. J. Barthéz, *Nouvelle Méchanique des Mouvemens de l'Homme et des Animaux.*

part of physiology, the only one in which it is possible to obtain, in the investigation of its objects, that degree of mathematical certainty so much sought after by every man of precision and of sound judgment.

Partial motions may yet further be studied as signs expressive of ideas. They compose what is called the language of action, and are supplemental to speech. The language of gestures, in its perfection, is found sufficient even to express the most subtle ideas, and the finest feeling, in the mute scenes known under the name of pantomimes. The gestures with which the man of most phlegm accompanies his discourse, are a language superadded to that which he speaks; they contribute to the exposition of the thought :—but what force in the man of passion do they not add to his expression! what power to his language! This eloquence of gesture, which was so often employed to move and sway the assembled multitude in the public place of Rome and Athens, was habitual to the orators of the antient republics; and the moment when Mark Antony uncovers and shews to the Roman people the bloody corse of the first of the Cæsars, is not the least eloquent passage of his harangue.

Thus, although the organ of voice is that which offers us the greatest abundance of resources for the expression of our ideas, for communication with our fellow-creatures,—though the hearing be the sense to which we must address ourselves to produce in them distinct, varied, and lasting impressions,—we do yet address ourselves to their touch and their sight when we would strongly move them by an energetic declaration of our desires. These three different languages are employed at once, when we lead a man towards an object, and at the same time point it out to him and bid him go there: touch and gesture are then auxiliary to speech, and testify in him who makes use of them a strong and resolute will. The motions of the eyes, the eye-brows, the eye-lids, the lips, and generally of all parts of the face, those of the upper limbs, and of the trunk itself, serve to express our passions as well as our ideas, are supplemental to the language of convention, and often betray it by saying the reverse of what it expresses. The study of gestures, of motions, and of attitudes, considered as signs of ideas and passions, is the department of metaphysicans, of painters, of sculptors, and physiognomists.*

CHAPTER IX.

OF VOICE AND SPEECH.

CXCIV. Of the Voice.—CXCV. Of Speech.—CXCVI. Of Singing and Stammering.—CXCVII. Dumbness and Ventriloquism.

CXCIV. *Of the voice.*—The voice is an appreciable sound, resulting from the vibrations which the air, expelled from the lungs, meets with in passing through the glottis. From this sound, articulated by the motions of the tongue, the lips, and other parts of the mouth, is produced *speech*, which may be defined *articulated voice*.

All animals furnished with a pulmonary organ have a voice; for it is sufficient to the production of this sound, that air, collected in any receiver, be

* See Condillac's Essay on the Origin of Human Knowledge; Buffon's Natural History of Man; Winkelman's Treatise on Art; Lavater's Essays on Physiognomy, with the important additions by M. Moreau (de la Sarthe), in the edition he has just published.

driven out in a body with a certain force, and that it meet on its passage with elastic and vibratory parts. Fish, that have only trachea, utter no sound; but this defect, which is certainly an impediment to the extent and facility of their relations, is in part made by the extreme velocity of their progressive motion.

The instrument of the voice is the larynx, a sort of cartilaginous box, placed at the upper end of the trachea. The thin and elastic cartilages which form its parietes are united by membranes, and moved on one another by many little muscles, called laryngeal. Of these five cartilages, three only are concerned in the production of voice; these are the arytænoid and the thyroid. The epiglottis is of no other use than to close on what we swallow the entrance of the windpipe; whilst the cricoid, situated at the lower part of the organ, serves it for a base, on which the arytænoid and the thyroid execute the motions by which the opening of the glottis is contracted or enlarged, for the formation of acute or grave tones.

This slit, from ten to eleven lines long in an adult, and from two to three wide where the width is greatest, is the most essential part of the larynx. It is really the organ of voice, which is gone at once, when, by opening the trachea or the larynx below it, the air is prevented from passing through it. Speech only is lost when the wound is above the place of the glottis; which shews that voice and speech are two distinct phenomena; one taking place in the larynx, and the other resulting from the action of divers parts of the mouth, and especially the lips.*

Are the different modifications of which the voice is susceptible dependent on the width or narrowness of the glottis, or on the tension or relaxation of the ligaments forming its sides? Must we believe, with Dodart, that the larynx is a wind instrument; or, with Ferrein, that it is a stringed instrument?

It is very true that the voice becomes stronger, fuller, and passes from the acute to the grave, as the glottis enlarges with the progress of age; that it remains always weaker and sharper in a woman, whose glottis is nearly a third smaller than a man's; but the tension or relaxation of the ligaments which form the sides of the glottis, (the vocal strings of Ferrein) may they not enable these ligaments to execute, in a given time, vibrations more or less prolonged, and more or less rapid, in such a manner, that if the air expelled from the lungs by expiration strike upon them in the state of tension, produced by the action of the crico-arytænoedi postici, which carry back the arytænoid cartilages to which the ligaments of the glottis are attached, whilst the thyroid cartilage, to which are attached the other extremities of the same ligaments, is carried forward by a sort of tilting, occasioned by the muscles connecting it with the cricoid cartilage (crico-thyroideus†), the voice will be shrill, that is, clear and piercing; whereas it would be grave if the arytænoid cartilages, being brought forwards by the action of the crico-arytænoidei obliqui and the thyro-arytænoidei muscles, the vocal strings relaxed, executed less frequent vibrations.

It has been objected to Ferrein, that to perform the office of vibrating strings, the ligaments of the glottis are neither dry, nor tense, nor insulated, —the three-fold condition required for the production of sound in the instruments to which this anatomist has compared the larynx; but, for all the incompleteness of their resemblance to strings, the ligaments of the glottis, similar to the vibratory bodies, serving as mouth-pieces to wind-instruments, such as the reed of the oboe, the mouth-hole of flutes, the lips themselves in

* See APPENDIX, Notes M M.

† The arytænoid muscle is used in the formation of acute sounds, for bringing together the two arytænoid cartilages.

the horn, do not the less contribute to the formation and varied inflexions of the vocal sound. It is the more difficult to set aside their influence altogether, inasmuch as their state of tension coincides always with the contraction of the glottis; and, the two conditions producing the same effect, it is difficult to determine if it be due to one rather than the other, as it is impossible to decide whether it be to the enlargement of the opening, or to the relaxation of the ligaments, that the grave tones are owing. A last reason, which, I think, should make the larynx be considered as serving at once the purposes of a wind and a stringed instrument, is, that the ligature or section of the recurrent nerves which gives to its muscles their contractility, takes away the voice; so that there is evidently required some kind of action in the sides of the opening.

When we wish to speak low, we contract but slightly, or not at all, the muscles of the larynx, whose action is entirely under the direction of the will. The column of air meeting, then, in its passage along the glottis, only relaxed parts, and little capable of vibration, the vocal sound is no longer produced. The permanent extinction of the voice must depend, in most cases, on palsy of the vocal or laryngeal muscles.

It appears, then, that, rejecting the opposite and exclusive explanations of Ferrein and Dodart, we are to consider the larynx as an instrument combining the advantages, and exhibiting the double mechanism, of wind and stringed instruments: it is on this account that it surpasses all musical instruments, by the extent, the perfection, and, above all, by the inexhaustible variety of its effects. There is no one that has heard, at a concert, a solo on the French horn by an able performer, but has been struck with the resemblance of the sounds of this instrument and those of the human voice. It is because the vibrating body at the mouth-piece of the instrument is alive; it is because the lips, like the sides of the glottis, are movable, the opening of the mouth dilates and contracts, and, at the same time, its edges are relaxed or stiffened by the contraction of the muscles of the lips.

The modifications of the voice depend not only on the varied sizes of the opening of the glottis, and of the contraction of the muscles of the larynx, but, further, on the varying disposition of the parts forming the pharynx, fauces, and mouth, as well as the length of the trachea. The singer who runs down the whole scale of sounds, from highest to lowest, visibly shortens the neck and the trachea, whilst in ascending he stretches them out.

The force of the voice* depends on the volume of air that may be expelled from the lungs at once, and on the degree of aptness in the parietes of the canals by which it is given out. Birds, whose body is all aerial, have a voice very strong for their bulk. Their trachea, furnished with a double larynx, is almost entirely cartilaginous.† It is especially so in certain screaming birds, as the jay and some others; whilst it is nearly membranous in the hedge-hog, a small quadruped, whose cries are almost imperceptible.

The hissing of serpents, and the croaking of frogs, are heard to some distance, because these creatures can send out a large quantity of air at once from their vesicular lungs; and in the latter, because the vocal strings are completely insulated from the coats of the larynx, with which in other animals they are continuous.

The voice of men is strong according to the capacity of the chest. It is always weaker after meals, when the stomach and intestines, distended with

* Sailors, and those that live on the banks of great rivers, have commonly strong voices, from being obliged to overpower, with the voice, the noise of the waves, which has constrained them to a great habitual exertion of its organs.

† See the Memoirs of M. Cuvier on the double larynx, and on the voice of birds.

food, push up the diaphragm and resist its descent. The voice, formed by the passage of the air along the glottis, acquires much force and intensity, and becomes much more sonorous, by the reverberations of the sound in the mouth and in the nasal cavities. It is weakened and disagreeably impaired when a polypus of the nasal canals, or of the throat, or the destruction of the roof of the mouth, prevents the air from passing along the nasal canals and their various sinuses. The voice is then said to be nasal, though, in truth, it suffers from want of the modifications it should receive in the cavities belonging to the nose.

CXCV. *Of speech.*—To *whisper*, is to articulate very weak sounds, which in truth deserve not the name of voice, since they scarcely exceed the sound which always accompanies the passage of air in expiration. Man only can articulate sound, and enjoys the gift of speech. The particular disposition of the mouth, of the tongue, and lips, makes all pronunciation impossible to quadrupeds. The monkey, in whom these parts have the same conformation as in man, would speak like him, if the air as it leaves the larynx were not diffused into the hyothyroid cavities, which are membranous in some, and cartilaginous and even bony in the howling monkey, whose cry is so hoarse and melancholy. Every time that the animal would utter his cry, these sacs swell, then empty themselves; so that he is not able, at will, to supply to the different parts of his mouth the sounds they might articulate.*

Articulated sounds are represented by letters which express their whole force. One cannot reflect on it all, without seeing what an advance man made towards the perfection of his nature, when he invented these signs for the preservation and transmission of his thoughts. The vocal sounds are expressed by the letters called *vowels*, that is to say, which the voice furnishes almost completely formed, and which need, for their articulation, nothing more than the more or less opening of the mouth, by the separation of the jaws and of the lips. We pronounce, without effort, the letters A, E, I, O, U; they are the first the child utters; they appear, besides, to cost him less study than consonants. These, which form the most numerous class of the letters of the alphabet, serve only, as their name indicates, to bind together the vowels. Their pronunciation is always less natural, and consequently more difficult. Accordingly, it is observed, that the most harmonious languages, the most grateful to the ear, are those which use fewest consonants and most vowels. It is in this point, especially, that the Greek tongue surpasses all, ancient and modern;† that of dead languages, Latin holds the second place; and, lastly, that Russian, Italian, and Spanish, are more agreeable in pronunciation than French, and still more than languages of Teutonic origin, as English, German, Dutch, Swedish, Danish, &c. Among some northern nations, all articulated sounds appear to issue from the nose or the throat, and make a disagreeable pronunciation,—no doubt because it requires greater effort; and he who listens sympathises in the difficulty which seems to be felt by him who speaks. Would it not seem that the inhabitants of cold countries have been led to use consonants rather than vowels, because the pronunciation, not requiring the same opening of the mouth, does not give the same room to the continual admission of cold air into the lungs? The gentle, pacific nature of the inhabitants of Otaheite, and of the other Fortunate Isles of the South Sea, is shewn in the words of their language, in which are abundance of vowels; whilst the hard and barbarous speech of the Esquimaux, of the people of Labrador and New Zealand, is the natural consequence of the rigour of

* In the ass an analogous structure is observed.

† ——— *Graiis dedit ore rotundo Musa loqui.*—Horat.

their climate, the barrenness of their soil, and their ferocious and warlike habits.

The distinction of letters into vowels and consonants has not been thought sufficient; they have been further distinguished, according to the parts which are more especially engaged in the mechanism of their pronunciation. Thus we mark the *labial*, *oral*, *nasal*, and *lingual vowels*; and *semi-vowels*, M, N, R, L, which bear different names, according as the tongue, in articulating them, strikes the roof of the mouth, the teeth, or the lips: lastly, *explosive* consonants, K, T, P, Q, G, D, B, P, and *sibilant*, H, X, Z, S, J, V, F, C, which are more numerous and more frequently employed in languages of more difficult pronunciation. If information on this subject could be of real utility, I should explain the mechanism of the pronunciation of every letter of the alphabet, at the risk of furnishing a new scene to the *Bourgeois Gentilhomme*.

CXCVI. *Of Singing.*—Singing is nothing more than voice modulated, that is, running over with varying rapidity the different degrees of the harmonic scale, passing from the grave to the acute, and from the acute to the grave, with expression too of the intermediate tones. Though, in general, our song is spoken, speech is not necessary to it. This action of the organs of the voice requires more efforts and motions than speech: the glottis enlarges or contracts, the larynx rises or descends, the neck stretches out, or is drawn in: inspiration is accelerated, prolonged or slackened; expiration is long, or short and abrupt. Accordingly, all these parts are more fatigued than by speech, and it is impossible for us to sing as long as we speak.

Whatever Rousseau may have said, in his Dictionary of Music, singing may be regarded as the most natural expression of the emotions of the soul, since the least civilised nations so use it, in their songs of war and love, of joy and mourning; and as every affection of the mind modifies in some way the voice, music, which is only imitated song, can by the aid of sounds paint love or rage, sadness or joy, fear or desire, can produce the emotions of these different states, can thus sway the course of our ideas, and direct at pleasure the operations of the understanding and the acts of will.* Of all the instruments which this art employs, the vocal organ of man is, indisputably, the most perfect, that from which the most agreeable combinations and the most varied may be obtained. Who is there that knows not the property of the human voice to lend itself to all accents, and to imitate all languages?† I will observe on the occasion of song, that it is especially consecrated to the expression of tender sentiments or movements of passion, and that it is turning it aside from its natural or primitive destination, to employ it in situations where no emotion can be supposed. It is this that makes the recitative of our operas so intolerably tiresome, and throws such ludicrousness over dialogues where the speakers converse singing on the most indifferent matters. Languages abounding in vowels are thereby fitted to song, and favour the growth of musical genius. It is, perhaps, their smooth and sonorous language that has given to the music of the Italians its superiority over that of other countries.‡ The declamation of the ancients was much more removed

* See Grétry, *Essai sur la Musique, &c.*

† See, in the *Aviceptologie Française*, or *Art de prendre toutes sortes d'Oiseaux*, the way in which they are drawn into snares by counterfeiting their song.

‡ This pre-eminence has been strongly contested, especially in France, where, towards the middle of the last century, a war arose on the subject, in which her whole literature, split into two factions, fought for the superiority of Piccini and Gluck. Out of the heaps of writings in verse and in prose with which the contest was carried on, a few epigrams will be remembered, the letter of Rousseau on French music, and the little work of d'Alembert on the liberty of music. Marmontel, too, has made these disputes the subject of an unpublished poem, under the name of *Voyages de Polymnie*.

than our own from the common tone of conversation, approached nearer to music, and might be noted like real song.

The pleasantness, the precision of the voice, the extent and variety of inflexions of which it is capable, depend on the good conformation of its organs, on the flexibility of the glottis, the elasticity of the cartilages, the particular disposition of the different parts of the mouth and nasal canals, &c. It would be enough that the two halves of the larynx, or the two nasal canals, were unequally developed, to prevent precision and distinctness of voice.

Of stammering.—Stammering is a vice of pronunciation too well known to make it necessary to define it. A tongue too bulky and thick,—a remarkable diminution of irritability, as in drunkenness, at the approach of apoplexy, and in certain fevers of a malignant kind,—the too great length of the frænum of the tongue, by hindering the readiness and ease of its motions,—become causes of stammering; or it may be produced by the want or bad arrangement of several teeth. The same causes, but especially the length of the frænum of the tongue, keep down this organ against the lower parietes of the mouth, and hinder its point from striking the anterior of the roof of the mouth with the quick stroke requisite for the pronunciation of the letter R. The name of *burr* is given to the defect of speaking.

CXCVII.—*Of dumbness and ventriloquism.*—As for dumbness, it may be either accidental or from birth. When by any accident, as from a gun-shot wound, a cancerous tumour which has rendered necessary the extirpation of part of the tongue, that organ, so far destroyed, is no longer able to apply itself to the different parts of the parietes of the mouth, and combine its motions with those of the lips,—then the person becomes dumb, that is to say, deprived of speech. He has still voice, or the faculty of uttering sounds; he may even articulate, if he supply, by mechanical means, the parts of the tongue, lips, or roof, the want of which hinders his pronunciation.

It is not so with the dumb from birth. Frequently all parts of the mouth are perfect in their conformation, and yet the child cannot attain to speech: such is the case of a little boy of three years and a half old, who has been brought to me to divide his frænum linguæ. Sometimes, however, the tongue adheres to the lower part of the mouth, because the internal membrane of that cavity is reflected over its upper surface long before it reaches the middle line of the inferior. In other cases, the edges of the tongue adhere to the gums.

Sometimes, also, the tongue is really paralytic: such was the case of the son of Crœsus, whose wonderful story is related by Herodotus.*

In the deaf and dumb from birth, the dumbness always arises from the deafness: this, at least, is what M. Sicard has observed in the great number of pupils committed to his care; which has led him to say, that in them the want of speech should bear the name not of dumbness, but of silence. It is owing entirely to the absolute ignorance of sounds, and of their force represented by the letters of the alphabet; the organs of voice shew no trace of injury; they are well fitted for fulfilling the purposes to which they were allotted by nature; but they remain inactive because the deaf child cannot be taught to use them.

It was necessary, therefore, as the ear was closed, to address to other senses the speech he must endeavour to imitate. His eye must be made to watch the motions† of the lips and the tongue; his hand to feel the vibra-

* This is the author's solution of the story, not Herodotus's statement, who says expressly the boy was deaf. But the conjecture is ingenious, and shews a possibility in the story, which, as Herodotus tells it, is impossible.—*J. C.*

† It is known that old men, grown deaf, fix their attention very closely on the motions of the lips, as well as on the varying expressions of the face, to see the words as well as thoughts of those who are speaking.—*J. C.*

tions and the utterance of sound ; and thence he must learn to use his organs of speech : this has been done. What Pereira had begun, Sicard has brought to perfection ; and such command of articulate sounds has been given to the deaf and dumb by birth, as has enabled them to utter words and connected discourse. Even something of inflexion of strong and weaker tones has been taught them, by using the arm as a regulator, as pedals are employed to modify the touches of the piano-forte..

But instruction to the deaf and dumb must be given them by another language. Written language they learn, not as a representative of speech, but as hieroglyphic characters for ideas ; and a manual language, in which each letter is expressed by the position of the fingers or hands, is used as a more convenient and rapid representation of that hieroglyphic language of written characters. It is by this that conversation with them is best carried on ; and it is with an ease and rapidity which astonishes those who, for the first time, are witnesses to the use of it.

Of ventriloquism.—To conclude this chapter, I have still to speak of a phenomenon, well worthy, by its singularity, of the attention of physiologists. It is known under the name of *ventriloquism*, because the voice, weak and little sonorous, appears to issue from the stomach. There was at the Palais Royal, at the Coffee-house de la Grotte, a man, who could carry on a dialogue so naturally, that you would think you were listening to the conversation of two people, at some distance from one another, and quite different in voice and tone. I have observed, that he was not inspiring while he spoke from his belly, but that less air came from his mouth and nostrils than in his ordinary speaking. Every time that he did so, he found a swelling in the epigastric region ; sometimes he felt wind moving lower down, and could not go on long together without fatigue.

I had at first conjectured, that in this man a great part of the air driven out by expiration did not issue from the mouth and nasal fossæ, but that, being swallowed and carried down into the stomach, it struck against some part of the digestive tube, and produced a real echo ; but having since observed with the greatest care this curious phenomenon in M. Fitz-James, who exhibits it in the highest perfection, I have satisfied myself that the name of ventriloquism no way suits it, since its whole mechanism consists in a slow, gradual, attenuated expiration, whether for that purpose the artist employ the power of the will upon the muscles of the parietes of the chest, or whether he hold the epiglottis slightly lowered, by means of the root of the tongue, of which he scarcely brings the point beyond the dental arches.

I find this long expiration always preceded by a strong inspiration, by means of which he introduces into his lungs a large quantity of air, of which he afterwards husbands the use. Accordingly, repletion of the stomach is a great hindrance to the action of M. Fitz-James, by preventing the descent of the diaphragm which the chest would require, to dilate itself for the full quantity of air the lungs should receive.

By accelerating or retarding expiration, he can imitate different voices, make it seem that the speakers, in a dialogue which he carries on by himself, stand at different distances, and produce illusion the more complete, the more perfect is his talent. No one equals M. Fitz-James in the art of deceiving, in this respect, the most wary and suspicious observer.

He can set his organ to five or six different tones, pass rapidly from one to the other, as he does when he represents a very eager discussion, in a popular society of the people, imitate the sound of a bell, and carry on singly a conversation, in which one might think that several persons, of different ages and sexes, were taking parts. But what completes the illusion, and espe-

cially distinguishes the art of the ventriloquist from that of the mimic, who can only counterfeit, consists in the power of so modulating his voice, that one is deceived as to the distance of the speaker, in such sort, that one voice comes from the street, another from a neighbouring apartment, that from one that had clambered up the roof of the house, &c. It is easy to discern the value of such a talent in the days of oracles.

SECOND CLASS.

FUNCTIONS SUBSERVIENT TO THE PRESERVATION OF THE SPECIES.

First Order.

THOSE GENERATIVE FUNCTIONS WHICH APPERTAIN TO BOTH SEXES.

CHAPTER X.

OF GENERATION.

CXCVIII. Differences of the Sexes.—CXCIX. Of Hermaphrodism.—CC. Of Generation.—CCI. Of the Male Organs of Generation.—CCII. Of the Female Organs of Generation.—CCIII. and CCIV. Of the Functions of the Generative Organs.—CCV. Of the Ovum and its Impregnation.—CCVI. Theories of Generation.

CXCVIII. *Differences of the sexes.*—The functions treated of in this chapter are not necessary to the life of the individual; but without them the human species would soon perish, for want of the power of reproduction: these functions, destined to preserve the species, are intrusted to two kinds of organs, belonging to the two sexes, of which they constitute the principal, though not the only difference.

Woman, in fact, does not differ from man in her genital organs merely, but likewise in her lower stature, in the delicacy of her organisation, in the predominance of the lymphatic and cellular systems, which softens down the projections of the muscles, and gives to all her limbs those rounded and graceful forms, of which we see in the Venus of Medicis the inimitable model. In woman, sensibility is also more exquisite, and, with less strength, her mobility is greater. The female skeleton, even, is easily distinguished from that of the male, by striking differences. The asperities of the bones are less prominent, the clavicle is less curved, the chest shorter but more expanded, the sternum shorter but wider, the pelvis more capacious, the thigh-bones more oblique,* &c. In a dissertation on physical beauty, read by Camper to the Academy of Design, at Amsterdam, this celebrated physiologist shewed, that in tracing the forms of the male and female body within two elliptical areas, of equal size in both, the female pelvis would extend beyond the ellipsis, and the shoulders be within; while in man the shoulders would reach beyond their ellipsis, and the pelvis be contained within its limits.

The general characters of the sexes are so marked, that it would be possible to distinguish a male merely by seeing a part of his body naked, even though this part should not be covered with hairs, and should have none of the principal attributes of virility. Should this difference of organisation and character be ascribed to the influence of the sexual organs upon the rest of the body? Does the uterus impress on the sex all its characteristic modifications, and is it just to say, with Van Helmont, "*Propter solum uterum mulier est, id quod est*"—the uterus alone makes woman what she is? Though this viscus very evidently reacts on the whole system of the female, and seems to draw under its control nearly the whole of the actions and affections of woman, I am, nevertheless, of opinion, that it is far from being the only cause of her distinguishing characteristics, since these may be recognised from the earliest period of life, when the uterine system is far from having attained its full activity. A very singular fact, recorded by Professor Caillot, in the second volume of the Memoirs of the Medical Society of Paris, proves, better than all the reasoning in the world, how much the character of the sex is independent of the influence of the uterus. A female was born and grew up with all the external characteristics of her sex. At the age of twenty-one

* Compare the beautiful plates of the male and female skeleton by Albinus and Sœmmering.

she wished to yield to her desires, but found it impracticable; there was nothing beyond the vulva, in other respects well formed. A small canal, between two and three lines in diameter, occupied the place of the vagina, and terminated in a cul de sac, and was about an inch in depth. The most accurate examinations, by introducing a sound into the bladder, and the finger up the rectum, discovered nothing like the uterus. With the finger in the rectum, the convexity of the sound in the bladder could be distinctly felt; so that it was evident, that between the lower part of the bladder and the anterior part of the rectum there lay no organ corresponding to the uterus. The young woman had never been subject to the periodical evacuation which accompanies or precedes the time of puberty. No hæmorrhage supplied the place of this excretion. She experienced none of the indispositions that are occasioned by the absence of menstruation; she enjoyed, on the contrary, the most perfect health; and she was deficient in none of the other characteristics of her sex, only that her breasts were small. At the age of twenty-six or twenty-seven she became subject to a pretty frequent evacuation of bloody urine. May not this affection, which recurred at irregular periods, be considered as a means by which nature supplied the deficiency of the menstrual evacuation? The bladder, in that case, would fulfil the office of the uterus, and its capillary vessels must have been considerably evolved.

The reproduction of the species is, in woman, the most important object of life; it is almost the only destination to which nature has called her, and the only duty she has to fulfil in human society. Wherever the earth is fruitful, and furnishes man with abundant means of providing for his wants, he dispenses with the services of woman in obtaining from it means of subsistence; he releases her from the burthen of social obligations. The Asiatic expects from the women he maintains in his seraglio, in a state of inactivity, nothing but pleasures, and children to perpetuate his race. The women of Otaheite have no employment but pleasure and the duties of mothers. Among some of the savage tribes of America, man, abusing the right of power, tyrannises, it is true, over woman, and, reserving to himself all the advantages of social life, makes her bear all its weight; but this exception does not invalidate the general law deduced from observation of all nations. Whatever withdraws woman from this primitive destination—whatever diverts her from this end, is to her injury: it is the scope of all her actions and habits; every thing in her physical organisation has evident reference to it. Of all the passions in woman love has the greatest sway; it has even been said to be her only passion. It is true that all the others are modified by it, and receive from it a peculiar cast, which distinguishes them from those of man.*

We shall proceed no further into the examination of the general differences which characterise the two sexes: no one has entered more deeply into this subject, or has treated it in a more interesting manner, that M. Roussel, in his work entitled, "*Système Physique et Morale de la Femme.*"

CXCIX. *Of hermaphrodism.*—Hermaphrodism, or the union of the two sexes in the same individual, is impossible in man and in the numerous class of red-blooded animals. There is on record no well-authenticated case of such a combination; and all the hermaphrodites that have been hitherto met with were beings imperfectly formed, in whom imperfect male organs, or female organs unnaturally enlarged, rendered the sex dubious. None was ever found that had the power by itself of begetting a similar being to itself:

* Fontenelle used to say of the devotion of some women: "*One may see that love has been here.*" It has been said in speaking of St. Theresa: "*To love God is still to love.*" Thomas maintains that, "*With women a man is more than a nation.*" "*Love is but an episode in the life of man; it is the whole history of the life of woman.*" —MADAME DE STAEL.

the greater number were incapable of reproduction: the imperfection, or the faulty conformation of their organs, condemned them to barrenness. Such was the case with the hermaphrodite mentioned by Petit, of Namur, in the Memoirs of the Academy of Sciences; with that one whose case is related by Maret, in the Memoirs of the Academy of Dijon; and with all those to be found in the records of the Medical Society, which contain the greatest number of facts of this kind.

But though in man, and in all beings that most resemble him in their organisation, complete hermaphrodism has never been met with, it is a frequent occurrence among the white-blooded animals, and especially among the plants, that occupy the lowest part of the scale of organised beings. The same is observed in polypi, in several kinds of worms, in oysters, and snails. The latter present a singular variety of hermaphrodism, in this, that the male and female organs being combined in the same individual, it is still singly not capable of generation, but is obliged to copulate with another being, likewise an hermaphrodite, so as to receive, from friction and other means of irritation, the excitement to the act of reproduction.

In the immense tribe of monœcia plants, the male and female organs are combined on one stalk, and even sometimes within the same flower. A number of stamina surrounded one or more pistils, shed on the stigma their fertilising dust or pollen, which is conveyed along the canal of the style into the ovary, there to impregnate the seeds by means of which the species are perpetuated. The same vegetable species containing sometimes male and female individuals, the sexes may be at considerable distances from one another; the seminal dust is in that case conveyed by the air from the male to the female. This is the case with palm-trees, on which Gleditsch made his first observations on the generation of plants, hemp, spinage, mercurialis, &c.

CC. *Of generation of man.*—It is a distinction of the human species, that in them the functions of generation are not under the influence of the seasons. The lower animals, on the contrary, draw together and pair at stated periods of the year, and seem afterwards to forget the enjoyments of love, that they may attend to their other necessities. Thus, wolves and foxes copulate in the middle of winter, deer in autumn, most birds in spring. Man alone seeks his partner at all seasons of the year, and impregnates her under all latitudes and in all temperatures. This privilege is not so much the consequence of his peculiar constitution, as a result which he derives from his industry: protected by the shelters which he constructs against the inclemency of the seasons and the variations of the atmosphere, always capable of gratifying his physical wants by help of the stores which his foresight has led him to collect, he can at all times indulge in the enjoyments of love. The domestic animals, which we have in great measure removed from the influence of external causes, bring forth almost indiscriminately at all seasons of the year. To prove still further that it is from counteracting, by the resources of his industry, the influence of nature, that man has succeeded in resisting the influence of the seasons in the reproduction of his species, I may observe, that this effect of temperature is more absolute the farther the species is from man: hence the spawn of fishes and frogs is productive sooner or later, according to the earliness or lateness of the seasons; and thus a great number of insects depend on the heat of the weather for their powers of reproduction, and for their existence.

Aristotle, Galen, and their verbose commentators, have expressed the analogy which subsists between the organs of generation in the two sexes by saying, that they differ only in their position, being external in man and internal in woman. There is, in fact, a considerable resemblance between the

ovaria and the testicles, the Fallopian tubes and the vasa deferentia, the uterus and the vesiculæ seminales, the vagina, the external organs of generation in women, and the male penis. The former secrete the seminal fluid, and furnish in man or in woman a matter essential to generation (*ovaria and testicles*). The Fallopian tubes, like the vasa deferentia, convey this fluid into receptacles, where it has to remain for some time (*uterus and vesiculæ seminales*). These contractile cavities, which serve as reservoirs to the semen or its product, part with these substances when they have remained within them a sufficient length of time. Lastly, the vagina and penis serve to expel them. However striking such analogies may be, we are not justified in inferring a perfect resemblance between the organs of generation in the two sexes. Each of them fulfils, in the act of reproduction, functions perfectly distinct, though of reciprocal necessity.

CCI. *Of the male organs of generation.*—The prolific fluid is secreted by the testicles: these organs are two in number, covered by several coats, one of which, covered by the skin, and known under the name of scrotum, resembles a bag, containing both these organs: it contracts on the application of cold, is relaxed by heat, and possesses a degree of contractility more evident than in the other parts of the cutaneous tissue. The dartos forms a second cellular envelope, common to each testicle. The tunica vaginalis, a serous membrane, affords an immediate covering to them, and, reflecting itself over their surface, is disposed with regard to them as the peritonæum with regard to the abdominal viscera; that is, it does not contain them within its cavity. Lastly, the testicles are covered by a fibrous, white, thick, and very consistent membrane: it is termed tunica albuginea, from the inner surface of which there arises a considerable number of membranous laminæ, which, crossing one another within its cavity, form cells containing a yellowish vascular substance. This substance, contained within the tunica albuginea, has so little consistence, that it would very soon be dissolved if the testicle were stripped of its outer covering. It is formed by the seminiferous tubes, which are small capillary vessels, extremely tortuous and coiled on themselves, arising, probably, from the extremities of the spermatic arteries, all directed towards the upper part of the oval formed by the testicles joining in this place, and forming about ten or twelve tubes, which unite into a cord situated within the tunica albuginea, called the *corpus Highmorianum.* The ten or twelve ducts, which unite into a fasciculus and form this cord, pass through the membrane within which they are contained, unite into a single canal, which is convoluted, and forms a substance called the epididymis. This canal, formed by the union of the ducts of the corpus Highmorianum, at first convoluted on itself, becomes less and less tortuous as it approaches the lower extremity of the testicle: there it bends back, and ascends, under the name of *vas deferens*, along the spermatic cord as far as the inguinal ring, by which it enters the abdominal cavity. The vasa deferentia, though of the size of a quill, have, nevertheless, a very small cavity; and it is not easy to say why a capillary tube should have such thick parietes, and nearly as hard as cartilage.

The semen, secreted by the testicles, is formed from the blood conveyed to them by the spermatic arteries,—long, slender, and very tortuous vessels, arising from the aorta, at a very acute angle. This fluid is filtered through the seminiferous tubes, passes into those of the corpus Highmorianum, and thence into the vasa deferentia, which, after they have entered the abdomen, terminate into the vesiculæ seminales, and deposit into them the spermatic fluid. The delicacy of the organisation of the testicle, and the delicacy of the vessels along which the semen is conveyed, account for its tendency to

congestion, and for the difficulty with which a resolution of this affection is obtained.

The spermatic fluid passes from the vasa deferentia into the vesiculæ seminales, notwithstanding the retrograde direction of their course. The cavities serving as receptacles to the semen resemble in this respect the gall-bladder. Notwithstanding the unfavourable direction in which the ducts of the liver and of the testicles join their respective receptacles, they nevertheless convey their fluids into the latter; the bile, because the ductus choledochus is very much narrowed where it passes through the coats of the duodenum, especially when this viscus is empty; the semen, because the duct along which it is conveyed, penetrating through the prostate gland, and opening into the urethra by a very narrow orifice, flows back more readily into the vesiculæ seminales than from the vas deferens into the ejaculatory duct.

The vesiculæ seminales form two membranous receptacles, of different capacity in different individuals—larger in young people and adults than in children and old people. Their cavity is divided into a number of cells; they are lined with a mucous membrane, which secretes, in considerable quantity, a viscid humour that mingles with the semen, increases its quantity, and serves as a vehicle to it. The situation of the vesiculæ seminales, between the rectum, the levatores ani, and the posterior part of the bladder, promotes the excretion of their contents, (which is chiefly brought about by the contraction of their parietes,) by the compression of the levatores ani, which are in a state of convulsion at the moment of emission. Animals that are not provided with these seminal receptacles, remain a considerable time in a state of copulation, the prolific fluid necessary to impregnation having to be secreted during the time that the copulation lasts, and flowing in drops.

The ducts formed by the union of the vesiculæ seminales with the vasa deferentia, pass the prostate gland, and open, by separate orifices, into the urethra, at the bottom of a lacuna, near the verumontanum. The glandular body in which they are enclosed, and which contains both the neck of the bladder and the beginning of the urethra, does not exist in women. The mucous and whitish fluid, secreted by the prostate, is conveyed by ten or twelve orifices into the urethra. This prostatic fluid mingles with the semen, adds to its quantity, and is perhaps emitted first, in order to lubricate the internal surface of the canal, and prepare it for the passage of the seminal fluid, by rendering the internal surface of the urethra more slippery.

The use of the urethra is, not only to convey the semen out of the body, but likewise to serve in the excretion of the urine, and to form a part of the penis. The latter, destined to convey the prolific fluid into the female organs of generation, must be in a state of erection to perform this function completely. Erection being a phenomenon of structure, that of the penis will be considered after the description of the female organs of generation.*

CCII. *Of the female organs of generation.*—I shall not adopt the anatomical arrangement generally followed in this description, but, classing in three divisions the different parts which in women are subservient to the genital functions, I shall speak first of the ovaria and Fallopian tubes, then of the uterus, and, in the last place, of the vagina and external parts.

The ovaria, situated in the female pelvis, connected to the uterus by a ligament, receive the vessels and nerves which in women are sent to the testicles; they resemble in form the latter, but are somewhat smaller. Do the ovaria secrete a fluid, which, by mixing with the male semen, produces the

* See APPENDIX, Note N N.

new being, or is there detached from them, at the moment of conception, an ovum which the semen vivifies? Whatever opinion is adopted, one is compelled to admit, that the ovaria prepare a substance essential to generation, since females in whom these parts have been extirpated are rendered barren.

It is, likewise, unquestionably, along these membranous tubes, called Fallopian, that this substance, whatever it may be, furnished by the ovaria, passes into the uterus, into which one of their extremities opens; while the other extremity, broad and fringed, lies loose in the cavity of the pelvis, supported by a small duplicature of the peritonæum, but undergoes a state of erection, and applies itself to the ovarium, during the act of coition, and forms a continuous canal between that organ and the cavity of the uterus. The external orifice of the Fallopian tube, called *corpus fimbriatum*, has been found thus grasping the ovarium, in females opened immediately after coition. It may happen from a malformation of the parts, that the Fallopian tube may not be able to apply itself to the ovarium. I dissected, at the *Hôpital de la Charité*, the body of a woman who had been barren; and found the corpora fimbriata, or the expanded terminations of the Fallopian tubes, adhering to the lateral parietes of the pelvis, so that it was impossible they should perform the motions required for impregnation.

The uterus, lying in the pelvis, between the rectum and bladder, is a hollow viscus, in which the fœtus grows till the period of birth. Its internal part has been found separated into two cavities, opening in some cases in the same vagina, and at others terminating in a vagina that was double only in the immediate vicinity of the uterus. Valisnieri mentions the case of a woman who had a double uterus, the one opening in the vagina, and the other communicating with the rectum. Though the muscularity of the parietes of the uterus becomes manifest in proportion as this organ enlarges during the process of pregnancy, this hollow muscle may be said to differ from other muscular organs by the arrangement of its fibres, which it is difficult to discover while its cavity is empty, and which it is even impossible completely to unravel while it contains the fœtus: its most remarkable distinguishing character is its singular property of dilating and stretching itself, and, at the same time, of gaining in thickness instead of becoming thinner.

The vagina is remarkable only by the soft, wrinkled, and easily dilated structure of its parietes. The upper extremity of this oblique canal, which is directed upward and backward, embraces the cervix of the uterus, while its lower orifice is surrounded by a spongy body, whose cells fill with blood and expel it, like the corpora cavernosa of the penis and clitoris. It is called plexus retiforme; its turgescence, during erection, contracts the orifice of the vagina; the contraction of the constrictor muscles, which answers the purpose of the accelerator urinæ in man, and which lies over this plexus retiforme, surrounds, like it, the entrance of the vagina, and may, in the same manner, contract the orifice of this canal.

Besides, this external orifice is furnished, in women who have had no connexion with men, with a membranous fold, varying in breadth, generally semicircular, and called hymen. Its existence is considered by many as the most certain sign of virginity. But all the marks by which it has been attempted to obtain a certainty of the presence of virginity are very equivocal.* The relaxed state of the parts, from a great quantity of mucus, in a woman subject to fluor albus, or from the blood of the menstrual discharge, may make the hymen yield, and not rupture; so that a woman might seem a virgin without being such; while another woman, who has not lost her

* "Attamen prima Venus debet esse cruenta."—Haller.

virginity, might, from illness, have her hymen destroyed. There are, in the last place, persons in whom the hymen is so indistinct, that several anatomists have doubted its existence.*

The other external parts of generation, which are easily discovered without the aid of dissection, cannot be considered as merely ornamental; all are, as will be shewn presently, of real utility. The folds of skin which form the labia and the nymphæ yield during the delivery of the fœtus. These duplicatures not only unfold themselves, but likewise undergo a degree of extension, their tissue being moister, softer, and more extensible than that of the skin. The mons veneris, the hairs which cover it, the clitoris, which resembles an imperfect penis, seem merely organs of voluptuousness; but is not pleasure itself an element in the act by which the human species is reproduced?†

CCIII. *Of the functions of the generative organs.*—When a chemical, mechanical, or mental irritation, excites the action of the genital organs, the penis elongates itself, becomes turgid and stiff, from the accumulation of blood within the cells of the corpus cavernosum, and within those of the corpus spongiosum of the urethra.‡ The turgescence of these two parts of the penis should be simultaneous to render the erection complete. It has been thought that this phenomenon might be accounted for by the compression of the pudic veins, which are situated between the symphysis pubis and the root of the penis, which, as long as the erection lasts, is compressed against the bone by the erector muscles. But, far from elevating the penis, the muscles of the perinæum, especially the ischio-cavernosus (*erectores penis*) tend to depress it. The blood which distends the corpora cavernosa of the penis, and the corpus spongiosum of the urethra and glands, which is itself the expanded extremity of the urethra, does not stagnate in their cells, only there is a greater quantity of blood in them than usual; the irritation increasing in a remarkable manner the action of the arteries. Erection, always proportioned to the degree of the stimulus, ceases when the cause of irritation no longer acts on the penis; in the same manner that an inflammatory tumour is discussed when the cause is removed.|| In this voluptuous dilatation, the urethra is brought into a state of erection, being put on the stretch by the penis, which is elongated, its curves are straightened, the irritation is propagated from the external to the internal parts, to the vesiculæ seminales, and the testicles; these swell, and their secretion is increased, as they receive a gentle degree of motion from the action of the scrotum, which becomes wrinkled, and draws them up towards the abdomen, and, by the action of the cremaster muscle, whose expansion forms between the tunica vaginalis and the dartos what has been improperly called the tunica erythroidea, they empty themselves with the greater ease along the vasa deferentia, which decrease in length as the testicles rise, and which participate in the concussion affecting these organs.

The concussions of the cremaster on the testicle, or on the vasa deferentia, promote in so important a manner the secretion and excretion of the semen, that this little muscle is found in animals whose testicles never leave the ab-

* It nevertheless always exists, but its size is very various. In some females it completely closes the vagina, and in this case it causes retention of the menses. In other cases, the occlusion not being complete, fecundation may take place by means of a very small opening, and without introduction.

† See APPENDIX, Notes N N.

‡ "Penis adest ità, constructus, ut stimulo corporeo sive mentali irritatus, turgeat et obrigescat, seque erigat, posteà detumescat, et collabatur."—CREVE.

|| The animal heat is somewhat augmented during erection as well as in inflammation. The temperature of the blossoms of the arum rises several degrees above that of the atmosphere at the moment of impregnation.

domen, but remain within that cavity on the sides of the lumbar region, as was observed by Hunter in the hedge-hog and the ram. This fact of comparative anatomy shews that the cremaster is of use, not merely in suspending the testicles, as its name indicates, since in the animals above mentioned they return into the abdomen towards the organ on which they are to act.

When irritation is carried to a certain length, it acts on the vesiculæ seminales, and these on the fluid which fills their cavity, and they expel it by the spasmodic contraction of their membranous parietes, assisted in this excretion by the levatores ani (CCI.) The prostate gland, and the mucous glands of the urethra, furnish a viscid substance, calculated to promote the evacuation of the seminal fluid, which is emitted in jets more or less rapid.

CCIV. The human semen is never emitted in a state of purity, that is, such as it is prepared by the testicles: it is even conjectured that the mucous fluid of the vesiculæ seminales forms the greatest part of it. It is this mucus which eunuchs emit in considerable quantity. The fluid secreted by the prostate gland, and by the mucous glands of the urethra, affect it likewise by uniting with it.

On being received into a vessel, it exhales a peculiar smell, like that of the pollen of a great number of plants; for example, of the chesnut-tree. It consists of two parts, the one thick and in clots, while the other is viscid, white, and more fluid. The proportion of the fluid of the semi-concrete part is greater in proportion as the person is weaker, and as the emission of semen is more frequently repeated. It soon liquefies, by losing part of its weight, which always exceeds that of water, in which it becomes soluble, though it was not so at first. On being analysed by M. Vauquelin, it was found to contain, of water 90 centimes, of animal mucilage 6, phosphate of lime 3, soda 1. It is in consequence of this last alkali that it is enabled to turn syrup of violets to a green colour. The animal mucilage is not pure albumen, but rather a gelatinous mucus, on which the qualities of the semen appear particularly to depend, such as its insolubility in water, and spontaneous liquefaction.

On being examined with the microscope, the semen is seen to contain small animalcules, with a rounded head, a tapering tail, and moving with rapidity. Is the liquefaction of the glutinous and viscid parts of the semen owing to the motion of these creatures? These microscopic animalcules are to be detected in the semen only at the period of puberty.* It has been thought that they shunned the light: authors have even gone the length of describing their ways and their diseases. The imagination has had much to do with all that naturalists have fancied they saw in these creatures, which they made subservient to their explanations of the mechanism of reproduction. However, it must be confessed, that in all the animal fluids, and in the juices of many plants, a certain number of these animalcules may be detected by means of the microscope.

* The author states in his last edition, on the authority of one observer only, that animalculæ are not found in the semen of individuals affected with syphilis. He also observes, that he has frequently had reason, in the course of his practice, to impute sterility in the male to the existence of the lues venerea: this latter circumstance, however, may be otherwise explained than by supposing that the seminal animalculæ are not generated during this disease. Indeed, the existence of those animalculæ is a matter of much doubt. We believe that what has been usually supposed to be such, are nothing more than the minute portions of some one of the very different secretions mentioned above as constituting the seminal fluid, in the act of more intimate mechanical mixture, or of union, with those of the others. The appearance of animalculæ may be also exhibited by the secretion of any single organ or part; for, as all secreted fluids are not actually homogeneous, their minuter portions, which differ in colour, consistence, &c. from the more abundant and more aqueous portion, would very probably give rise to the deception in question.—*J. C.*

A spasmodic contraction affects, during the expulsion of the semen, not only the organs of generation, but the whole body; and the moment of emission is accompanied by a commotion of all parts of the frame; so that it should seem, says Bordeu, that in that instant Nature forgot every other function, and was solely engaged in collecting her strength and directing it to one organ. This general spasm, this, as it were, epileptic convulsion, is followed by universal depression: this physical lassitude is attended with a sensation of sadness, which is not without enjoyment. Does this peculiar sensation, which, according to Lucretius, mingles grief with the most lively enjoyment of which we are capable, depend on the fatigue of the organs, or, in truth, as some metaphysicians have imagined, on the confused and distant notion that occurs to the soul of its own dissolution?

The penis does not enter the uterus, though the semen does. The os tincæ offers too small a slit, and its thick edges are, besides, in contact. It would be difficult to conceive that this straight passage should admit even the seminal fluid, if it were not known that in the moment of copulation, the uterus, from irritation, draws together, and inhales, by real suction, the semen which it craves. Plato compared this organ to an animal living within another animal, controlling all the actions of the living economy, burning to sate itself with the liquor of the male, and disgesting it to form a new individual.

The great thickness of the cervix of the uterus has given room for reasonable doubt whether or no its orifice could dilate sufficiently to admit a fluid of the consistency of semen. Some, therefore, have thought that it was not this fluid itself that penetrated into the cavity of the uterus, but the subtlest of its parts, the most spiritualised, a prolific vapour, to which they have given the name of *aura seminalis*; but, besides that the semen has been found in the uterus in animals opened immediately after copulation, Spallanzani, in his experiments on the fecundation of frogs, of salamanders, and toads, perceived that, to enable the eggs to produce, it was not enough to expose them to the vapour which rises from the seminal fluid of the male, and that nothing was effected unless the fluid semen actually touched them, though in ever so small a quantity.

It has been said that the uterus dilates to receive the semen, constricts itself to retain it, and that this spasmodic contraction of the uterus, felt, as Galen assures us, by women who preserve enough *sang-froid* to make observations in that situation, was the most undoubted sign that could be had of the success of the copulation. It is, no doubt, to ensure this retention that it is customary to throw cold water on the females of some domestic animals when they go too eagerly to the male. The spasm of the skin, occasioned by the cold striking it, affects the uterus, and hinders the flowing back of the semen which has been thrown into its cavity.

It has also seemed that women conceived more easily, for a little time, after menstruation; when the mouth of the uterus is less exactly closed than usual.

The seminal fluid, thrown into the cavity of the uterus, passes along the Fallopian tubes to the ovaria. It does not diffuse itself in the cavity of the abdomen, because the membranous duct seizes the ovarium, which corresponds to it, grasps it closely, and establishes an uninterrupted canal from this organ to the uterus. The ovarium, bedewed by the semen, irritated by its contact, lets a fluid escape, or perhaps a little ovum, which passes into the uterus the same way that the semen reached it. All that remains to be said concerning the mechanism of generation must not be delivered as real, but

merely as probable; such is the darkness with which Nature has chosen to envelope this great mystery of the living economy.*

After distinguishing the true from the probable, an indispensable duty in every science of facts and observations, like physiology, I shall proceed to state the hypothesis which appears to me the likeliest on the manner in which the two sexes concur in the production of the new being.

CCV. *Of the ovum and its impregnation.*—The germs pre-exist in the ovaria of the females, not that they are there since the creation of the world, as Bonnet believed, and all who embraced the doctrine of that metaphysical naturalist; but the ova containing the germs are formed by the proper action of the ovarium which secretes them; a fresh proof that all the phenomena of organised bodies, whether for the preservation of the species or of the individual, are effected in the way of secretions. The ovum, produced by the elaboration of the blood which the spermatic vessels carry to the ovaria, contains the lineaments of the new being; but it is only the sketch or carcass of it, if this may be applied to what has not yet lived. The seminal fluid must bring it out of this state of inactivity, and, with something of an electrical power, waken it into life. The eggs laid by a maiden hen will never hatch, though there are in them the rudiments of the chick. The eggs of a frog that has been kept apart from the male during the whole time of spawning, putrefy in the vessel of water they are kept in: if the male, on the contrary, sprinkles them with his semen, as they quitted her, they will speedily shew some developement of life. Their putrefaction may be prevented, and themselves animated, by shedding on them the spermatic fluid, obtained by the process employed by Spallanzani, in his admirable experiments on artificial impregnation.

It is especially to the labours of this able observer that we owe what has been unveiled of the mystery of generation, and of the part which each sex bears in this function. It is almost proved that the male co-operates in this function, only by supplying the vivifying principle that must animate the individuals of which the female furnishes the germs; and that thus his part is the least essential. It is not so difficult as may be imagined to explain upon this system the striking resemblances which are frequently seen between fathers and sons. The imperceptible embryo has, at most, the consistency of a slightly viscous glue. Such a body must be exceedingly impressible, and the semen of the male, applied to its surface, must impress on it powerful modifications. The action of the fluid on this yet tender embryo must be like that of a seal, which stamps on the soft wax its own image. The impression is the deeper, the resemblance the more striking, according to the spirit and energy with which the male performed the act of reproduction.

The seminal fluid of the male may not merely act on the surface of the gelatinous and nearly liquid germ, and modify it externally, but it may penetrate so soft a substance, and impress on it inward changes. It is thus that we are able to explain, not only hereditary likeness, but also hereditary diseases. Nevertheless, it does appear that the interior parts are derived chiefly from the female, while the outward parts are especially influenced by the male; for, when two animals of different species copulate, their mule resembles the sire outwardly, and the dam within. It is difficult to shew good reason for the want of the generative faculty in mules. Why are their sexual parts, so well developed, altogether barren? What secret defect frustrates their action? And why do certain mules, among birds, propagate, and in the same manner hybrid plants, which are real mules, and not quadrupeds?

The impregnation of the ovum is effected in the ovarium itself, to which

* See APPENDIX, Notes N N.

the semen is conveyed, as has been said. The ovum, stirred by the action of the semen, and of the Fallopian tube, detaches itself from the organ which has produced it, and descends into the uterus, by the peristaltic contractions of the Fallopian tube. This canal is susceptible of a retrograde motion. It may be conceived possible that, having stretched itself by a real erection, to convey the semen to the ovarium, it must in its return upon itself cause a flow of the fluid its cavity contains in a completely inverted direction.* This retrograde motion, as Nisbet observes, is assisted by a sort of collapse succeeding the excitation which coition had produced; for the experiments of Darwin prove that the weakness of the vessels is the cause of this mode of action in their parietes. Spongy as the urethra of man, the Fallopian tube brings back the ovum from the ovarium to the uterus. The extra-uterine fœtations afford the proof that matters are carried on in the manner we have stated. Since fœtuses have been found developed in the ovarium, in the Fallopian tube, and even in the cavity of the abdomen, when the detached ovum has escaped from the grasp of the corpus fimbriatum,† one must admit that it follows the course which has been described.

The ovaria, like the testicles, swell and enlarge at the time of puberty. They shrink and wither in some degree when the woman is no longer fit for generation. On examination a few days after conception one of the ovaria is larger than the other, and shews a little yellowish vesicle, which dries up in the course of pregnancy, so that towards the end there remains nothing in place but a very small cicatrix. Is this vesicle the outermost covering of the ovum, in which the germ is enclosed, and which is torn to allow its escape? The observations of Haller prove that the corpus luteum is formed by the remains of a vesicle that has burst at the moment of conception, and allowed the fluid it contained to escape. In an ewe opened a few minutes after coition, you may see, in one of the ovaria, a vesicle larger than the others, torn with a little wound, of which the lips are still bloody. Inflammation comes on in the torn coats of the small vesicle, fleshy granulations appear, then sink, and a scar shews the place where it had been. The number of these cicatrices is proportioned to that of the fœtuses. It is not known how long the germ, detached from the ovarium, remains within the Fallopian tube before it reaches the cavity of the uterus. Valisnieri and Haller had never been able to perceive it directly in this viscus before the seventeenth day.

The obstruction of the tubes, as well as the defect or diseased affection of the ovaria, may cause barrenness. Morgagni speaks, on this head, of certain courtezans in whom the tubes were entirely obliterated by the thickening of

* See the Notes N N in the APPENDIX on this subject.

† In extra-uterine abdominal conceptions, the ovum, which the tube could not hold or seize, rolls into the hypogastric region, and there adheres to some point of the peritoneum. It is found attached to the mesentery, to the colon, to the rectum, or to the external part of the uterus, growing there, and developed by the vascular communication which takes place at the adhesion; but the vessels of the peritoneum are insufficient for the entire developement of the fœtus, which dies for want of nourishment in the first months of pregnancy. The adhesion of the ovum to the peritoneum is easily accounted for, by the irritation it occasions: it may be considered as a foreign body, determining by its presence inflammation of the membrane with which it lies in contact, and uniting with it because it brings to this act its own share of vitality. It is really an union of two living parts, not unlike to that which takes place between the bleeding lips of a wound, or between the pleura pulmonalis and the pleura costalis, &c.

But as the serous membranes contain, in their tissue, capillaries so fine, that when in a healthy state the blood does not shew its colour in them, their vessels never develope themselves sufficiently to transmit to the ovum, which has adhered to them, a due supply of this fluid. The mucous membranes receiving more blood are able to supply more; but the placenta cannot adhere to them in extra-uterine conception. The membrane which lines the tube, belongs, in fact, as much to the serous as to the mucous membranes; it establishes, as is well known, the only point of communication there is between the two kinds of membranes.

their parietes; the consequence, evidently, of the habitual orgasm in which they had been kept by too frequent excitation. The structure of these parietes must make obstructions of the Fallopian tubes very easy. Their tissue is spongy, vascular, and seems susceptible of erection, like the corpus cavernosum of the penis and of the clitoris. Their internal coat (the point of union between the serous membrane which lines the abdomen, and the mucous membrane within the uterus) partakes in the inflammation of both. I have often been consulted by young women on the cause of their sterility: by a close investigation of the causes from which it might have arisen, I have always found that they had had, at different periods of life, inflammation of the lower part of the abdomen. A young woman, after obstinate suppression of the menses, exhibited all the symptoms of inflammation of the peritoneum: a year afterwards she married, but never became pregnant. A woman recovered from puerperal fever, ensuing upon a very difficult first labour; from that time, with all the appearance of the stoutest health, she has never again been a mother.

Do the two testicles and the two ovaria contain the separate germs of males and females? Are the latter, as has been guessed, contained in the left ovarium, and males in the right? and may we procreate sexes at pleasure, by varying the attitude of copulation? This old opinion, lately revived, besides wanting all foundation, is formally confuted by facts: nothing is more common than to see men who have, from some accident, lost a testicle, procreating sexes indifferently. Women, with an ovarium deficient, or the Fallopian tube obliterated on one side, have produced both boys and girls. Dr. Jadelot presented to the Society of the School of Medicine, in Paris, a uterus wanting the right tube and ovarium; and nothing indicated that they had ever existed. On inquiry concerning this woman, it appeared that she had been delivered of a boy and two girls. Haller quotes similar cases. The cause, then, which determines the sex, altogether eludes our investigation. Does that one of the two who exerts most energy in the act of coition, impress its sex on the offspring? I cannot tell; but I think I have observed that the marriage of young people, where both are glowing with love and youth, most frequently produces daughters, whilst boys are ordinarily the consequence of the union of a middle-aged or elderly man with a younger woman.*

CCVI. *Theories of generation.*—The antique system of the mixture of the semen in the cavity of the uterus, set forth in the writings of Hippocrates and Galen, is still that of many physiologists. In this system the mixed fluids may be considered as an extract from all parts of the body, male or female. A generative faculty† disposes them suitably for the formation of the new individual. Buffon has further particularised the facts which this hypothesis requires, and displays its improbability. Each part, he says, furnishes molecules, which he calls organic, and these molecules, coming from the eyes, the ears, &c. of the man and the woman, arrange themselves round an internal mould, of which he admits the existence, which mould forms the basis of the edifice, and comes from the male, probably, if it be a boy, from the female if a girl. Reason rejects a theory which gives no explanation of the production of the placenta, and of the membranes covering the fœtus; it is, moreover, directly disproved by the good conformation of children born of parents who, not happening to have certain organs and limbs, could not certainly supply the proper molecules for their formation in the child.

* This opinion has not been confirmed by the observations of other physiologists.—*J. C.*

† All that Blumenbach has said on the force of formation (*nisus formativus*) applies to this generative faculty; it is only a new name given to an old idea.

The system of the ovarists, which at this time stands highest in favour, numbers amongst its supporters Harvey, Stenon, Malpighi, Valisnieri, Duhamel, Nuck, Littre, Swammerdam, Haller, Spallanzani, Bonnet, &c. These admit the distinction of animals into oviparous and viviparous in the sense only that these last hatch within, and break their shell before they are brought forth. Lastly, Leuwenhoek, Hartsoeker, Boerhaave, Mery, Werheyen, Cowper, &c. have added to the opinion of the ovarists, that the seed of the male contains a multitude of spermatic animalcules, all capable of becoming, by developement, beings similar to their father. These animalcules push forward, along the tubes, upon the ovaria: there a general engagement takes place, in which all are slain, save only one, who, master of the field of battle, finds the trumph of his victory within the ovum that has been prepared for him. This system, which is not the most probable in the world, assigns to the male the greater part in the work of generation, since the female is made to furnish merely the coverings of the fœtus.

It would be to no purpose to unfold, more at large, opinions hazarded on a subject so obscure. What I have said is enough to shew that those parts of nature which most obstinately elude our curiosity, and afford most scope to our imaginations, are those which men believe they know the best, and on which they speak with most confidence and prolixity:—so true is it, as Condillac has observed, that we have never so much to say as when we set out from false principles.

Second Order.

FUNCTIONS EXCLUSIVELY BELONGING TO THE FEMALE.

CHAPTER XI.

OF THE FŒTUS, PARTURITION, AND LACTATION.

CCVII. Of Uterine Gestation.—CCVIII. History of the Fœtus.—CCIX. to CCXI. Of the Circulation in the Fœtus.—CCXII. Of the Nourishment of the Fœtus.—CCXIII. Of Monstrous Fœtuses.—CCXIV. Of the Coverings of the Fœtus.—CCXV. Of the natural Term of Utero-gestation.—CCXVI. and CCXVII. Of Parturition.—CCXVIII. Of Twins.—CCXIX. Of Superfœtation.—CCXX. and CCXXI. Of Suckling.—CCXXII. Of the Physical and Chemical Properties of Milk.—CCXXIII. Of the State of the Lungs and Foramen Ovale in some Infants.

CCVII. *Of uterine gestation.*—From the moment of conception there begins in woman, both in the motion of the solids and the composition of the fluids, a remarkable alteration. The change that has taken place shews itself in all her functions: she exhales a peculiar odour; the child she suckles refuses the breast, or takes it with reluctance, and soon falls away, if left in the hands of such a nurse.

Nature, occupied over her work, seems to forget every thing else to bring it to perfection. It has been observed, that in times of contagious diseases, even where the plague raged, pregnant women were least exposed to infection; but, at the same time, when they are seized with affections, which in other persons or at another season would be without danger, they sink under them, because these diseases, though at first very slight, easily put on a malignant character. The progress of mortal diseases is retarded: a phthisical woman, and who has only a few months to live, shall prolong her life through the whole term of gestation. The consolidation of fractures is nothing slower, though Fabricius Hildanus pretends that the state of pregnancy puts a complete stop to it.

I have never been able to find any difference in the time of formation of callus between pregnant women and others. M. Boyer avows the same opinion.* Among the authors who have asserted that fractures could not consolidate during pregnancy, some have conjectured that this depends on nature, who is busy in directing the humours to the uterus, forgetting in some sort every other function, and omitting to institute the process necessary to the cure. But, as we shall see, whatever may be the importance of the uterus, charged during pregnancy with the fruit of conception, the fœtus is merely an organ added to the organs of the mother, and assimilating to itself the juices it receives from the uterine vessels. It does not hinder the other parts from getting their nourishment: they all go on living, and separating to themselves the juices their existence or their functions require. Haller ascribes the difficulty with which the broken ends unite in pregnant women, to the great quantity of earthy matter which the fœtus draws off from the

* Leçons de M. Boyer, sur les Maladies des Os, redigées en un Traité complet de ces Maladies, par A. Richerand. 2 vols. 8vo.

mother. This opinion will not stand; for, as I have shewn in my preliminary discourse, the phosphate of lime has but little to do in the work of reunion, which chiefly goes on by changes in that part of the bone which is really organic. Besides, this hypothesis would imply that consolidation were as difficult in nurses, whose milk carries off a large quantity of phosphate of lime. Yet it has not been observed that the formation of callus is more difficult during suckling. Lastly, on this, as on all occasions, experience is more effectual than reasoning; now, experience shews that the time required for the formation of callus in pregnant women is not sensibly longer than in their ordinary state.

Meanwhile, the uterus, imbued with prolific fluid, swells, to avail myself of the expression of a modern, like a lip stung by a bee: it becomes a centre of fluxion, towards which the humours tend from all quarters. The diameter of its vessels increases with the thickness of its parietes: these soften, and their muscular nature becomes more marked.* Till the end of the third month the only appearance of pregnancy is in the suspension of menstruation: the uterus, of which the cervix has yet undergone no change, has concentrated itself behind the pubis, but very soon it rises above the upper outlet of the pelvis, pushing upwards the intestines and the rest of the abdominal viscera. Towards the end of pregnancy it rises above the umbilicus, its fundus comes in contact with the arch of the colon, and reaches sometimes to the epigastric region. The compression it exerts on the organs of digestion explains the loathings and the nausea which belong to the state of pregnancy. The derangement of sensibility, by the affection of the great sympathetics, accounts equally for those depraved tastes, those fantastic appetites, which the ignorant think it so important to gratify. When the term of pregnancy draws near, respiration is oppressed, the diaphragm forced upward by the abdominal viscera, descends with difficulty; accordingly, nature has, as much as possible, delayed this moment of oppression, by giving the lower part of the abdomen a great capacity, at the expense of the chest, which in woman is much shorter than in men.

If the growth of the fœtus, its size, the quantity of liquor amnii, and the developement of the uterus, were always the same, we might settle the height to which this last organ must rise at each stage of pregnancy; but these conditions vary so much in every individual, that the terms one might assign would suit but a small number: let it suffice to have spoken of the extremes. The uterus tends to rise directly upwards: while enclosed within the pelvis it preserves this direction; but, as soon as it has passed the upper outlet of the pelvis, it is no longer supported, and inclines forwards, backwards, or to the sides. These inclinations, if they go a certain length, constitute those vices of situation which accoucheurs call obliquities of the uterus. Their direction is determined by the disposition of the parts: accordingly, they almost always are forwards, either because the upper outlet of the pelvis is naturally so inclined, and forms, with the horizon, an angle of forty-five degrees, or because the lumbar column, being convex, pushes the uterus against the anterior parietes, which yields the easier the more frequent pregnancy has been.

The dilatation of the uterus is not the effect of a simple distension of its parietes, since these, far from stretching thinner as the viscus grows in size, thicken progressively, on the contrary, by the dilatation of vessels of all sorts, and the afflux of humours. In this sort of vegetation the uterus is really active, and does not give way to any efforts of the fœtus. The cervix

* According to M. Lobstein, the uterus during pregnancy is analogous to an organ in a state of chronic inflammation.—*J. C.*

of this viscus, which, from its greater consistency, had at first resisted dilatation, ends by yielding to the efforts of the fibres of the fundus on the edges of the os tincæ; the edges of that opening are attenuated, the cervix effaced, the orifice enlarges, and you may feel through its parietes the fœtus plunged in the waters which its membranes contain.

Towards the term of gestation the discharge of urine is more frequent, because the bladder, under compression, cannot contain it in any quantity; the lower extremities are œdematous, and the veins of the legs varicose: women are also more exposed to hæmorrhoids; and these effects depend on the compression of the vessels which bring back the blood and the lymph of the inferior parts, as the cramps to which pregnant women are subject depend on that of the sacral nerve. The groins are alike painful, and there are felt in them twitchings which must be ascribed to congestion in the round ligaments of the uterus.* Lastly, the skin of the anterior parietes of the lower part of the abdomen, distended beyond measure, cracks when that of the neighbouring parts has yielded as much as it could.

Before explaining how the uterus expels the fœtus and its coverings at the term of gestation, let us consider a little this fruit of conception, let us study its developement, let us examine the nature of the relations which it holds with its mother.

CCVIII. *History of the fœtus.*—The interior of the uterus, for a short period after the instant of conception, shews nothing that leads to a knowledge of the existence of its product. But at the end of a few days there appears a membranous, transparent vesicle, filled with a liquid, trembling jelly, discovering no trace of organisation and life. But the little ovum begins to grow, parts of the gelatinous fluid assume more consistence, losing at the same time their transparency: one may then distinguish the first rudiments of parts—an imperfect appearance of the head, trunk, and limbs. The small ovum, free at first in the cavity of the uterus, contracts adhesion to this viscus: its whole exterior surface becomes shaggy, and this sort of vegetation is no where more marked than in the situation to be occupied by the placenta. Meantime, towards the seventeenth day, the parts, which shewed merely a homogeneous, semi-transparent mass, discover a more determinate structure. A red point appears in the spot of the heart—it is the heart itself, distinguishable by the pulsations of its cavities, and the motions of the molecules of the red liquid that fills them. Because the heart is the *punctum saliens*, it is not, therefore, to be concluded that it is the *primum vivens*. All our parts are formed together, all are coeval, as Charles Bonnet has said; only they discover themselves earlier or later to the eye of the observer, according as the nature of their organisation is adapted to the reflexion of light.† Were we to admit a successive order in the formation of our organs, the brain and the nervous system might exist before the heart, without being perceptible from their transparency.

Meanwhile, red lines, setting off from the heart, sketch the course of the larger vessels, and seem agitated by the action of these tubes, whose parietes are still semi-transparent. As the blood, or rather its red part, extends from

* These ligaments, as well as the uterus, manifest during gestation their muscular character: their vessels enlarge, and their fibres become more apparent, according to the observations of M. Jules Cloquet, made on the bodies of several females who had died soon after child-birth.

See the Note N N, last referred to, in the Appendix, for the Changes which the Nerves of the Uterus and its Appendages undergo during Pregnancy.—*J. C.*

† The opinion of Bonnet alluded to above rests on no observation that can even lend it a collateral support. We have every reason, on the contrary, to infer, that a successive order in the formation of our organs is observed. See some remarks on this subject in the Appendix, Notes O O.

the centre to the circumference, the forms become more determinate, the parts unfold and grow rapidly: points quite opaque are seen, and the form of the fœtus may be distinguished. Bent upon itself, the fœtus is not unlike a French bean, suspended by the umbilical cord, which, as I shall mention by-and-by, formed with the fœtus and its coverings, proceeds in growth with them: it swims amidst the liquor amnii, and changes its position the more easily as the space in which it is enclosed is greater compared to its size. As it grows it stretches out a little, without ceasing, however, to retain its bent posture (CLXV.): the head composes the greater part of its body; the upper limbs, like little buds, pullulate first, then the lower limbs; the feet and the hands appear immediately attached to the trunk; the fingers and toes shew themselves like little papillæ. Of all the organs of sense, the eyes are the first apparent: they are discernible as two little black spots; and by the end of the first month the eye-lids are produced, and cover them. The mouth, at first gaping, closes by the drawing together of the lips, towards the end of the third month. During the fourth, a reddish-coloured fat begins to be deposited in the cells of the mucous tissue, and the muscles already exert some action. The growth is ever more rapid as the fœtus draws nearer to its birth. It is impossible to assign the weight and the length of the fœtus at the different stages of pregnancy, since the time of conception is never very certain; and further, the progess of growth varying much, one fœtus at six months shall be as large as another at the full term. Nevertheless, at the time of birth, the body is commonly eighteen inches long, and weighs from seven to eight pounds.

The secretion of bile, like that of the fat, seems to begin towards the middle of gestation, and tinges the meconium yellow,—a mucus previously colourless, which fills the digestive tube; a little while after the hairs grow; the nails are formed about the sixth or seventh month; and a very thin membrane which closed the pupil, tears, by what mechanism is unknown, and the pupil is seen. The kidneys, at first manifold, that is to say, formed each of from seventeen to eighteen separate glandular lobules, unite and form on each side a single viscus. Lastly, the testicles, placed at first at the side of the lumbar column and aorta, near the origin of the spermatic arteries and veins, then carried along the iliac vessels to the inguinal rings, directed by a cellular cord, (which Hunter calls the *gubernaculum testis*,) pass through this opening, carrying along with them the portion of the peritoneum which is to form their tunica vaginalis, and the inferior fibres of the smaller oblique muscle.

This covering of the testicles, furnished by the peritoneum, not only covers these organs, and is reflected again over them, but also rises, in adults, about half an inch high, along the lower part of the spermatic cord. If it do not reach, it is said, to the inguinal ring, it is because the whole portion which, after birth, extended from this opening to near the testicle, has been decomposed, and is reduced to a cellular tissue. Upon reflecting on the causes of the spontaneous decomposition of a portion of this peritoneal prolongation, it occurred to me, that nothing was less proved, or more improbable; in fact, in earliest life, the testicles, which have passed out from the abdomen by the inguinal rings, are very little removed from this opening. The portion of tunica vaginalis, which is continued upon the cord of the spermatic vessels, rises up to the rings, and even extends beyond them; communicating with the peritoneum, as is sometimes seen in congenital bubonocele. It is only in the progress of life that the testicles descend into the scrotum, still departing from the opening which gave them passage; so that in adults the prolongation covering at first the whole cord, which just after birth was not more than

a few lines long, is found to cover only its lower part when it is lengthened some inches, without being decomposed; a phenomenon which it is as difficult to conceive as to explain. This opinion, suggested for the first time in the first edition of this work, is now almost universally received.*

CCIX. *Of the circulation in the fœtus.*—The principal difference that is found between the fœtus and the new-born child, besides the inactivity of the senses, and the repose of the muscles subject to volition, consists of the manner in which the circulation is carried on. Too feeble to assimilate to its own substance foreign substances, the fœtus receives from its mother aliments ready prepared. The arteries of the uterus receive a large supply of blood: this is not all employed for the nourishment of the organ itself, but passes, in great part, from the mother to the child, being poured by the uterine vessels into the cells of a spongy substance, adhering on one side to the uterus, and on the other to the ovum which contains the fœtus.

This cellulo-vascular body, known under the name of placenta, is, as well as the covering of the fœtus and the fœtus itself, a product of the act of generation. Though it adheres commonly to the fundus of the uterus, it may adhere to any other point of its parietes; sometimes, even, it is placed on its orifice; a circumstance which always makes delivery difficult. The side by which it is united to the internal face of the uterus is uneven, covered with mamillary projections (*cotyledons*), which are sunk in corresponding cells of the parietes of the uterus, the internal surface of which loses, as it developes itself, the smoothness which it had while empty, is furrowed with depressions destined to receive the placenta, and studded with projections which penetrate into the cells of the latter.

The uterine arteries, which are so large and numerous in the gravid uterus, that Cruickshank compares them to quills, and perhaps, likewise, the lymphatic vessels, or those conveying merely colourless blood, throw out on the surface of the placenta, and within its spongy tissue, the arterial blood of the mother: according to some, these vessels exhale only the serous part of the blood, and, according to others, a chylous, lymphatic, whitish, or milky substance.† These fluids, effused within the cells of the placenta, are absorbed by the numerous minute divisions of the umbilical vein, which by their union form the trunk of this vessel.

The umbilical vein, arising from the interior of the placenta, by numerous

* See APPENDIX, Notes O O.

† A German physician, Schreger, has suggested a very ingenious opinion on the mode of circulation between the mother and child. He believes that the uterine arteries pour out nothing but serum into the cells of the placenta. This serum is absorbed by the lymphatics, whose existence in this organ and in the umbilical cord he infers from analogy; in which, however, no one has yet succeeded in injecting them. These vessels convey it to the thoracic duct, whence it is poured into the left subclavian vein, and at last reaches the heart, which sends it along the aorta. It returns to the placenta by the umbilical arteries, after being converted into blood by the actions of the organs of the fœtus. This serosity, after undergoing the process of sanguification, returns to the fœtus by the umbilical vein, and, following the well-known course of the fœtal circulation, is subservient to the nourishment of its organs. The branches of the umbilical arteries and veins, ramified in the placenta and communicating together in this spongy tissue, reject through their lateral pores that which can no longer serve to the maintenance of the fœtus. This residue of nutrition, deposited in the cells of the placenta, is absorbed by the lymphatics of the uterus, which carry it back into the mass of the fluids of the mother. Not to mention the impossibility of demonstrating the presence of the lymphatics in the placenta, or in the umbilical cord, Schreger's hypothesis is attended with two objections. How does the nutritious fluid, coming from the mother and sent along the aorta of the fœtus to every part of its body, return to the placenta, to be brought back again by the umbilical vein? Absorption scarcely goes on in the fœtus: the unctuous substance with which the body of the fœtus is covered, prevents that function from taking place on the surface of the body. It goes on with very little more activity within the body; the excrementitious secretions scarcely exist before birth: whatever is conveyed to the fœtus is employed in the developement of its organs; hence its growth is so rapid.

See the remarks on the Function of the Placenta, Notes O O, in the APPENDIX, last referred to.

branches, detaches itself from it and goes towards the umbilicus of the child, enters his body at that aperture, ascends, in a fold of the peritoneum, behind the recti muscles, to the anterior extremity of the sulcus of the liver, and goes along the anterior of this fissure, sending a number of branches to the lobes of that viscus, especially to the left lobe. On reaching the right extremity of the transverse fissure, where this last meets the anterior-posterior, it unites, in part, with the sinus of the vena portæ hepatica, while the remainder of the vessel, called ductus venosus, follows the original direction, and opens into the ascending or inferior vena cava, very near to the spot where this vein pours its contents into the right auricle of the heart.

CCX.—The arterial blood, which flows along the umbilical vein, acquires the properties of venous blood, and combines with hydrogen and carbon, and parts with its vivifying qualities in flowing along the vessels of the mother and the tortuous vessels of the placenta. It parts with these principles, and again becomes vivified by circulating through the liver, which, at this period of life, fulfils the function which after birth is committed to the lungs. Hence the liver and brain form the greatest part of the weight of a new-born child. The former alone occupies the greatest part of the abdomen. It acquires this bulk by assimilating to itself the hydrogen and carbon of the umbilical blood. Its substance is adipose, oily, and contains these two principles in a considerable proportion. The secretion of the bile, and that of the fat, the only secretions that are manifestly carried on in the fœtus, may, besides, supply very well the want of respiration.*

The blood conveyed by the umbilical vein in the lower vena cava, and deposited by that vein into the right auricle, does not unite with that which is brought by the descending cava from the upper parts, for, as was observed elsewhere, the orifices of these two vessels not being directly opposed to each other, the columns of blood which flow in them do not meet each other. That which is brought by the lower cava passes through the foramen ovale, towards which the mouth of that vessel is turned ; it passes into the left auricle, thence into the left ventricle, without circulating through the lungs, which, containing no air, and being dense and indurated, could not have received it : the contractions of the left ventricle send it into the aorta, and the force of its impetus is broken by striking against the great arch of this artery. It enters into the vessels which arise from it, and these convey it directly to the brain and upper parts. This blood is the most pure, the most oxygenated, and that which comes most immediately from the placenta ; it has not yet circulated in the body of the fœtus, with the exception of a very small quantity brought from the pelvis and lower parts, for the blood which comes from the abdominal viscera is purified in passing through the liver. The other parts of the body receive, on the contrary, blood imperfectly oxygenated, since the very inconsiderable quantity which the contractions of the left ventricle and the aorta have not been able to send into the vessels arising from the arch of this vessel, mixes with the venous blood which is brought by the ductus arteriosus, immediately below this curvature. Hence growth, which is always relative, not only in respect to the quantity, but likewise to the vivifying qualities of arterial blood, is much more rapid before birth in the upper parts, so that the brain alone constitutes the greatest part of the body ; and the shoulders, the chest, and the upper extremities, are developed in a much greater degree than the abdomen, and especially than the pelvis and lower extremities.

The blood which is brought by the descending cava from the upper parts of the body of the fœtus, passes into the right ventricle, which forces it into

* See APPENDIX, Notes O O.

the pulmonary artery: this vessel sends only two small branches to the lungs, and terminates, by a vessel called the ductus arteriosus, in the aorta, immediately below the origin of the left subclavian artery. The aorta, at its origin, is therefore filled with arterial blood, sent towards the upper parts of the body by the contraction of the left ventricle, while the remainder of this artery contains venous blood, which is expelled by the combined action of both ventricles.

It is impossible, in this arrangement, not to recognise an evident design. In fact, if the whole force of the heart had been exerted to send the blood towards the brain, the delicate texture of this viscus would have been injured by it; the combined action of the two ventricles was, on the contrary, required, to enable the blood to circulate along the extensive and tortuous channels of the umbilical cord and placenta. The aorta, on reaching the body of the fourth or fifth lumbar vertebræ, divides into the two umbilical arteries; these send to the pelvis and to the lower parts only very insignificant branches, which convey blood that contains a very small quantity of oxygen; they then bend along the sides of the bladder, incline inwards, approach towards the urachus, pass out of the abdomen at the umbilicus, and, joining the umbilical vein, which had entered through the same opening into the body of the fœtus, form with it the umbilical cord.

CCXI.—The length of the umbilical cord, measured from the umbilicus to the placenta, is from twenty to twenty-four inches. It may be not above six inches long, or may greatly exceed that length, as is proved by a case of M. Baudelocque, in which the umbilical cord was fifty-seven inches in length, and passed seven times round the child's neck, which circumstance, by the way, shews that the fœtus moves in its mother's womb. Of the three vessels which form the umbilical cord, two, which are the smallest, have an arterial structure, though they convey blood that is truly venous, while the umbilical vein carries arterial blood to the fœtus. The umbilical arteries divide on reaching the placenta, and are lost in its substance, in a multitude of vessels, whose extremities deposit into the areolæ of its tissue the blood coming from the fœtus, and which is to be returned to the mother. Does the course of injection from the umbilical vein into the arteries prove that there exists an anastomoses between the extremities of these vessels?

The fœtus is connected to the mother by the umbilical cord and placenta: the veins, or the lymphatics of the uterus, and perhaps both these sets of vessels, take up, in the spongy tissue of the placenta, the blood that has been employed in the nutrition of the fœtus, and return it to the mother, that, after undergoing a change by the action of her organs, and especially by that of the atmospherical air, by means of the pulmonary circulation, it may become fit for the nourishment of the fœtus. Whether we inject the uterine vessels, or whether we force the wax along the umbilical vein, it never fills but a part of the placenta, which has led to the division of this substance into two parts, the one belonging to the mother, which has been called uterine, the other, called the fœtal portion, which forms a part of the umbilical cord.

The vessels of the mother do not, therefore, anastomose with those of the fœtus within the placenta: the circulation is not continued from the one to the other. If the communication were immediate, the beats of the pulse of the child ought to be simultaneous with those of the mother, whereas they are much more frequent, as may be observed, at the time of birth, before the division of the umbilical cord. If the veins of a bitch ready to whelp are opened, the animal dies of hæmorrhage, and her body remains bloodless. The placenta, however, is empty only in the part that adheres to the uterus;

the rest of the placenta, as well as the fœtus, are filled with blood, as usual. It is obvious, that if the vessels of the uterus had been directly continuous with those of the placenta, delivery would not have taken place without their being torn : alarming hæmorrhage, inflammation, and even suppuration of the uterus, would have been the consequence. Lastly, the force with which the heart and arteries of the mother impel the blood along her vessels, would have been attended with danger to the organs of the fœtus, which are too soft to sustain without injury so violent a shock. Though the placenta and the umbilical cord form the bond of union between the fœtus and the mother, it must be confessed that they belong chiefly to the former, and may be considered as a continuation of its body.

CCXII. *Of the nourishment of the fœtus.*—The existence of the fœtus is solely vegetative ; he is continually drawing from the juices which the vessels of the mother send to the placenta, what is to serve for his nourishment and growth. He may be considered as a new organ, the product of conception, participating in general life, but having a peculiar life, and, to a certain degree, independent of that of the mother. Bent on himself, so as to occupy the least possible space, he cannot be considered as asleep ; for, not only are the organs of sense and of motion in a perfectly quiescent state, but, besides, several of the functions of assimilation are inactive, as digestion, respiration, and most of the secretions. The fœtus performs, in the midst of the liquor amnii, spontaneous motions, which accoucheurs reckon among the signs of pregnancy. The existence of these phenomena has been denied, and the displacement of the fœtus has been ascribed to a mere shaking of the body : this was asserted on the ground of the intimate connexion between respiration and muscular motion. It was said, that the blood of the fœtus, not being impregnated with oxygen in its passage through the lungs, contractility would not exist. But besides that a fact may be certain without being easily explained, it may be answered, that the mother fulfils this office for the fœtus, and sends it arterial blood, fitted to maintain the contractility of the muscles.

As we perform no motion but in virtue of impressions previously received, and as the organs of sense in the fœtus are completely inactive, it is not easy to say why it should move in the womb. The touch, however, is exerted when any part of the surface of the body of the fœtus comes in contact with the internal part of the cavity in which it is contained. Lastly, the internal impressions experienced by the great sympathetics may act as an occasional cause of such motions.

The fœtus is nourished, like every other organ, by appropriating to itself whatever is suited to its nature in the blood brought to it by the vessels of the uterus. The interception of this fluid by a ligature, or by compression of the umbilical cord, would occasion death, though not, as has been imagined, by a sudden and quick suffocation, but the action of the organs would become gradually weakened, and at last cease, when the fluids of the fœtus, being no longer vivified by the mixture of new juices from the mother, would be completely deprived of their nutritive parts. It is now well ascertained that the liquor amnii does not serve to the nutrition of the fœtus, whose mouth is closed, whose head is bent on his breast, and whose intestinal canal is filled with a fluid different from that in which the whole body is immersed. Besides, may not the unctuous substance with which the surface of the skin is covered, prevent the absorption which might otherwise take place from the outer part of the body ?*

* May not also this substance, which is the produce of the small sebaceous glands of the skin, prevent the cuticle from being macerated in the surrounding fluid, owing to its being re-

It was long believed that the fœtus was in an upright position during the first months of life, but that, towards the end of pregnancy, it fell into a different position, and lay with its head downwards. This erroneous opinion, believed from its antiquity, and because it was admitted by several physiologists, is completely refuted in Professor Baudelocque's work on midwifery. The absurdity of this hypothesis is manifest, if it be considered that the head of the embryo, the most bulky and weighty part of the body, must necessarily occupy the most depending part.

The plumpness and the strength of the fœtus do not altogether depend on the strength of the mother. Corpulent and strong women often bring forth puny children; while others, who are thin and feeble, bring forth children plump and healthy. Such instances, however, are exceptions to the general rule, as, *cæteris paribus*, the healthy state of the fœtus is to be estimated by that of the mother. The morbid condition of the fluids of the mother has a considerable influence on the health of the fœtus, and is, perhaps, the way in which hereditary diseases are transmitted, which diseases by others are ascribed to a diseased state of the semen.

The fœtus is subject to affections of various kinds, whether of spontaneous origin, or arising from a germ received from the mother. Fœtuses have been seen with cicatrices, which clearly shewed that solutions of continuity of various kinds had taken place. A child, born with the loss of some limb, has met with the accident in consequence of some affection experienced in the womb. Professor Chaussier having been called in to a case of this kind, found the hand and a portion of the fore-arm among the membranes.*

CCXIII. *Of monstrous fœtuses.*—As it is useful to study nature, even in her irregularities, I shall say a few words on the subject of monsters, adopting the arrangement proposed by Buffon, and dividing them into three classes: the first including monsters from excess, the second monsters from defect, the third including those in which there is a misplacement of organs. In the first are included those which have supernumerary limbs or fingers, or even two bodies joined in various ways. In the second, children born with a hare-lip, or who are deficient in some one part. In the last place, those monsters belong to the third class in which there is a general transposition of organs; when, for example, the heart, the spleen, and the sigmoid flexure of the colon, are on the right side, and the liver and cæcum on the left: those born with herniæ of different kinds likewise belong to this class. One may reckon, among these monstrous conformations, spots in the skin, the colour of which always resembles that of some of our fluids, but whose various forms are purely accidental, though, from prejudice one is apt to imagine some likeness to objects longed for by pregnant women accustomed to those fantastic appetites and longings so frequent during pregnancy.

Various attempts have been made to account for these unnatural formations; some, as Mallebranche, attributed them to the influence of the mother's imagination on the fœtus in the womb; others, as Maupertius, thought that her passions communicated to her humours irregular motions, which, acting with violence on the delicate body of the embryo, disturbed its structure. Disease, while the child is in utero, is a much more probable cause of such affections.

If two fœtuses, contained in one ovum, lie back to back, and if the surfaces at which they are in contact become affected with inflammation, it is easy to conceive that adhesion may take place between them. By placing in a

pulsive of water, and to its being retained closely applied to the cuticle by the fine downy hair, or pubescence, which thinly covers the skin during the early periods of existence?—*J. C.*

* See the APPENDIX, Notes O O.

confined vessel the fecundated ova of a tench or any other fish, the numerous young ones which are formed, not having space sufficient for their growth, adhere to each other, and fishes truly monstrous in their formation are produced.

When, from disease, or from an original malformation, the body of the fœtus is deficient in some of its parts, the others are better nourished, and grow to a large size. Hence, in acephalous monsters, as there is no brain, the blood which should be sent to that viscus going to the face, it acquires a remarkable enlargement.

One of the most curious of all the cases of monstrosities, depending on an original defect in the organisation of the germs, is that which was sent, a few years ago, by the Minister of the Interior, to the School of Medicine at Paris. I shall give an abstract of it from a more detailed account, drawn up with much accuracy and sagacity by M. Dupuytren.

A young man, thirteen years of age, had complained, from his infancy, of pain in the left side and lower part of the abdomen. This side had been prominent and contained a tumour from the earliest period of life. At the age of thirteen he was seized with fever, the tumour increased in bulk, and became very painful. Some days after, he voided by stool purulent and fœtid matters ; at the end of three months he became wasted by marasmus, he passed by stool a ball of hairs, and, in the course of a few weeks, died of consumption.

On opening his body, there was found in a cavity, in contact with the transverse arch of the colon, and communicating with it, some balls of hairs and an organised mass. The cyst, situated in the transverse mesocolon, near the colon, and externally to the digestive canal, communicated with the intestine. But this communication was recent and accidental, and one could planly see the remains of the septum between these cavities. The organised mass presented in its forms a great number of features of resemblance with the human fœtus, and, on dissection, no doubt could be entertained of its nature. There was discovered in it the trace of some of the organs of sense, a brain, a spinal marrow, very large nerves, muscles converted into a sort of fibrous matter, a skeleton consisting of a vertebral column, a head and pelvis, and limbs in an imperfect state ; lastly, a very short umbilical cord, attached to the transverse mesocolon at the outer part of the intestine, and an artery and vein, ramifying at each of their extremities, where they were in contact with the fœtus and with the individual which contained it. This much is sufficient to establish the distinct existence, as an individual, of this organised mass, though in other respects destitute of organs of digestion, of respiration, of the secretion of urine, and of generation. The absence, however, of a great number of the organs necessary to the maintenance of life, should make it be considered as one of those monstrous fœtuses not destined to live beyond the moment of birth. This fœtus was evidently contemporary with the boy to whose body it was attached. Similar to the product of extra-uterine conceptions, it received its nourishment from that which may be considered as its brother, and whose germ had originally enclosed its own. During the thirteen years of the life of Bissieu, (this was the name of the subject of this singular case,) the organised mass obtained from the mesocolon, by means of vessels of its own, the blood necessary for its existence : this blood, propelled by the organs of circulation into the body of the fœtus, returned afterwards to the mesocolon of the boy who had so long been to him as a mother. At last, the period fixed by nature for expulsion being arrived, and this expulsion being impracticable, the cyst became inflamed ; the inflammation extended to the intestine, the part which separated these two cavi-

ties were destroyed, and the cyst opened into the colon ; pus and hair were voided by stool, and the patient died of marasmus. The drawings of different parts of the body of this fœtus, taken by M. Cuvier and M. Jadelot, render this interesting case most complete. They will be published in the first volume of the transactions of the Academical Society, near the Faculty of Medicine at Paris.*

We ought not to be ready to place implicit confidence in the extraordinary stories contained in the older writers, and even in some of the moderns. In reading the periodical publications of the seventeenth and even of the eighteenth century, one is apt to wonder at the marvellous things which they contain. Among other strange cases, is that of a girl that was born with a pig's head ; another, of a woman who was delivered of an animal, in every respect like a pike. There was a time, says a philosopher, when philosophy consisted merely in seeing prodigies in nature.

CCXIV. *Of the coverings of the fœtus.*—The name of after-birth is given to the envelopes of the fœtus, because they are not expelled from the uterus till after the birth of the child. The ovoid sac, which contains the fœtus, is formed by two membranes in contact with each other. The name of chorion is given to that which, by its external and shaggy surface, adheres to the inside of the uterus : the other, a concentric membrane to the former, but of less thickness, and to be considered as the secretory organ of the fluid which fills the ovum, is called the amnion. The third envelope, admitted by Hunter, and called by that physiologist the membrana decidua, is nothing more than the lanuginous tissue presented by the external part of the chorion, after tearing the multitude of cellular and vascular filaments by means of which the ovum adheres to the uterus. The placenta is itself merely a thicker portion of nearly the same tissue in which the umbilical vessels are ramified. The uterus is also thicker at the part which corresponds to the placenta, because it is there that the communication of the fœtus with the mother is established.

The membrana decidua, a perfect epichorion, as it has been called by M. Chaussier, is the result of the generative orgasm. It is formed on the internal surface of the uterus from the irritation excited by the act of impregnation. It serves to unite the ovum to the interior of the uterus ; and, although the ovum may never reach this viscus, the decidua is developed, notwithstanding, on its internal surface. This circumstance is always observed in extrauterine fœtation.

Recent researches into the nature of the membranous tissue, by means of which the human ovum adheres to the interior of the womb, particularly the inquiries of MM. Moreau and Velpeau, have shewn that the deciduous membrane of Hunter, called the epichorion by Professor Chaussier, is in all respects a serous membrane, contiguous to itself, and adherent on one side to the interior of the uterus, on the other to the exterior of the chorion. This opinion respecting the medium of union between the fœtuses and uterus (according to which the ovum may be considered as being attached to the womb in the same manner as the viscera are to the abdomen) seems plausible, and, besides analogy, it has several authentic observations as to the existence of a contiguous and moistened surface existing in the substance of the decidua, in its favour. M. Desormeaux has long taught, in his lectures, that

* Mr. Young, of London, has communicated a case of the same kind, in a valuable paper inserted in the first volume of the Medico-Chirurgical Transactions. In Mr. Young's case, the fœtus was contained in a cyst that seemed to answer the purpose of membranes and placenta ; it was without a brain, but had imperfectly formed digestive viscera, and external organs of generation.—See vol. i. of the Medico-Chirurgical Transactions.—*T.*

the deciduous membrane is disposed after this manner, namely, that it forms a duplicature or is contiguous to itself; indeed, the beautiful plates of the impregnated uterus, by Dr. W. Hunter, shews this conformation.

The liquor amnii is a serous fluid, of a sweetish odour, and insipid taste, rendered slightly turbid by a milky substance which it holds suspended, and somewhat heavier than distilled water, 1·004. It is almost completely aqueous; albumine, soda, muriate of soda, and phosphate of lime, were discovered in it by MM. Buniva and Vauquelin, forming only 0·012 of the whole mass. It turns tincture of violets of a green colour, and reddens that of turnsole; a very remarkable circumstance, as is observed by the last-mentioned philosophers, and indicating the co-existence of an alkali and of an acid in a separate state. The latter is in so small a quantity, so volatile, and so soluble in the liquor amnii of woman, that it has never yet been obtained by itself: there is found, however, in the liquor amnii of the cow a peculiar acid, called by MM. Buniva and Vauquelin, the amniotic acid. The liquor amnii is in greater quantity in proportion to the size of the fœtus, according as the latter is nearer the period of its formation. It is the product of arterial exhalation. Its materials are supplied by the blood conveyed by the vessels of the uterus. This is proved, not merely by analogy, but likewise by observing the connexion between the qualities of the liquor amnii and the regimen of the mother. In a woman who had used mercurial friction in the course of her pregnancy, the liquor amnii was observed to whiten copper.

The fundus of the bladder in quadrupeds is continuous with a canal, of which the rudiments are observed in man, and which is called the urachus. This canal joins the umbilical vessels, passes out with them at the umbilicus, and terminates in a membranous sac between the chorion and the amnion: it is called the allantois; it is always found in the fœtus of the lower animals, but it is very indistinct, and often does not exist in man. Some anatomists say, they have seen the urachus arising from the human bladder, and which is commonly ligamentous, terminate in a small vesicle, which some of them compare to a melon seed; while others say its bulk does not exceed a millet or hemp seed. So small a vesicle can certainly answer no purpose; the urachus always forming a solid cord, seldom pervious, and even of very small bore in the part nearest the fundus of the bladder. The existence of these parts furnishes an additional proof of what was stated in speaking of the uses of the valve of the cæcum, viz. that there are in the animal body organs which answer no purpose, and which merely indicate the plan which Nature has followed in the reproduction of beings, and the gradations which she has uniformly observed in the divisions of the species.*

CCXV. *Of the natural term of utero-gestation.*—The fœtus may exist without the maternal influence, when arrived at the period of seven or eight months from the instant of conception. All accoucheurs agree that it may be delivered alive at this period, and that it stays two months longer in the uterus only that it may gain more strength, and be better fitted to resist the new impressions which it is to experience on coming into the world. A child, however, has been known to live, though born at the sixth month of pregnancy, in premature labour; but, in general, the child is the more likely to live when born at the usual period; that is, towards the end of the ninth solar month, or of the tenth lunar. It is observed, that children born at seven months, however robust they may prove afterwards, are very feeble when born, have their eyes closed, and are in a state of extreme debility and suffering during the two months which they ought to have spent in their mother's

* See APPENDIX, Notes O-O.

womb: this proves how necessary it is that gestation should be carried on to the end of the ninth solar month.

If the fœtus may live, though separated from its mother before the natural period, may it not, likewise, remain longer within the womb, grow with less rapidity, and be expelled some days, weeks, and even months later? How difficult therefore will it not be to assign a precise term, beyond which we shall not be able to admit the possibility of a late birth!

There are said to be authentic cases of children born more than ten months after conception; yet the laws, which cannot be founded on rare exceptions, do not allow of so long a period in deciding of the legitimacy of children born after the dissolution of matrimony.

CCXVI. *Of parturition.*—When the fœtus has remained sufficiently long within its mother's womb to acquire the degree of strength required for its insulated existence, it becomes separated from her, carrying along with it the parts which enclosed it, and by which it was connected to the uterus. Its expulsion from the uterus is called delivery. The most ridiculous opinions have been entertained with regard to the causes which determine the coming on of labour: according to some, Fabricius of Aquapendente for instance, it is the want of fresh air which makes the fœtus rupture its membranes; according to others, the fœtus is determined to the same process by the necessity of voiding the meconium, an excrementitious fluid which fills the intestinal canal. It has been said, that the fœtus was urged to it by the want of food, or that labour depends on the re-action of the fibres of the uterus, which, distended beyond measure, towards the end of pregnancy close on themselves, and overcome the resistance of the cervix uteri, which is thinned and gradually dilated. But if this last hypothesis be correct, and it is the only one that is at present in any esteem, how comes it, that in a woman whose uterus is of a determinate size, labour does not come on when there are twins at the end of four months and a half, by which period the same degree of distension would be produced as by one child at the full time?

It is very true, that for a fortnight, and even sometimes for a month, before labour, the uterus seems to be preparing for the expulsion of the fœtus. This, at least, may be inferred from the prominence of the cervix of the uterus, which may then, sometimes, be felt; and which is evidently produced by the membranes containing the waters, which insinuate themselves within the orifice of the uterus, when this organ contracts, and which collapse and recede when the uterus is relaxed.

The product of conception, after a certain time, reaches a period at which it may exist separated from the mother. When this period is arrived, the ovum in which it is contained detaches itself from the uterus by a mechanism in every respect similar to that by which the stalk of a ripe fruit drops from the bough on which it hung. Then, in all probability, the fœtus refuses to admit the blood sent to it by the umbilical vein; the placenta becomes affected with congestion; the stagnation of the fluid extends gradually to the uterus and to the neighbouring parts. Stimulated by their presence, these organs are called into action; the woman feels wandering, irregular pains, similar to cholic pains, which become more acute, are attended with a feeling of constriction, and act from above downwards, that is, from the fundus to the cervix of the uterus. This contractile cavity, assisted by the diaphragm and abdominal muscles, then acts with redoubled effort to expel its contents. The pains become more acute and frequent; the face red, the pulse full and accelerated the whole body seems to partake in the affection of the uterus, and is agitated with convulsive motions. The membranes, filled with the waters, force themselves, like a wedge, through the mouth of the uterus, whose edges are much

weakened; the throes of labour increase in strength and number, the membranes rupture, the liquor amnii escapes, the head of the child follows, and it soon clears the mouth of the uterus with most excruciating pains.

These pains are particularly severe when, the sacrum not being sufficiently concave, the nerves of the sacral plexus are violently compressed by the head of the fœtus; this part of the body almost always presents first; it passes through the upper outlet of the pelvis in an oblique direction, the occiput being turned forward, and corresponding to one of the acetabula, while the face is directed backward towards one of the sacro-iliac junctions. It passes thus along the greatest diameter of the pelvis; but in descending lower down in the pelvis, it describes a portion of a circle, and passes through the lower outlet of the pelvis at its greatest diameter, which is from the fore to the back part. The head descends through the vagina, appears outwardly, soon disengages itself, and is followed by the shoulders and the rest of the body. Thus it is that Nature, after having produced fecundation by an act attended with pleasure, expels the product of conception in the midst of pain.

CCXVII.—The passages along which the fœtus is carried out of the body would be too confined, in their ordinary state, to allow expulsion to take place without laceration, if, as I am going to explain, Nature had not disposed every thing to facilitate labour. In fact, Nature has not only formed the fœtal skull of several flexible pieces, separated by membranous unossified spaces, so as to allow the bones to move over one another, and the whole head to be reduced in size, in passing through the female pelvis; but she has, besides, united the bones of the pelvis in such a manner that their articulations become evidently relaxed towards the end of pregnancy. During the progress of utero-gestation, the fluids of the mother flow, in every direction, towards the pelvis and the parts which it contains; the ligamento-cartilaginous articulations of the pubes, of the sacrum, and loccyx, soaked in fluids, unite, with less firmness, the bones between which they are placed. Hence, being softened and swollen, they do not force themselves asunder like a wedge, by increasing their diameters, but facilitate the separation of the bones, by the passage of the head through the pelvis. It is on the relaxation of the articulations of the pelvis that the indication for the operation of dividing the symphysis pubis, rests; an operation performed successfully by Signault, and by Professor Alphonse Leroy. Analogy led very naturally to this operation, as is judiciously observed by M. Thouret, in the same manner that the invention and application of the forceps were founded on a consideration of the means employed by Nature to lessen the bulk of the child's head during the progress of labour.

The foresight of Nature is not limited to the facilitating the motion on one another of the osseous parts of the skull of the fœtus, and of the pelvis of the mother; her care extends to the soft parts of the latter: these are soaked in mucus, so as to relax their tissue, several days before parturition, and are so disposed, as was already observed (CCI.), that they may, without rupture or violence, and by the mere unfolding of the folds of the skin, yield to a considerable degree. As the placenta and the membranes are not expelled immediately after the fœtus, it is customary to separate them, by dividing the umbilical cord near the navel. It is unnecessary to tie this cord at the part near the mother, every communication being intercepted between the placenta and the uterus, so that no blood could flow but that of the placenta. Not so, however, with the part nearest the fœtus: though the changes which take place in the circulation at the moment when the chest is dilated, and allows the air to distend the pulmonary tissue, divert the blood from the umbilical vessels,—yet these changes in the circulation of the fluids

might come on slowly, from the weakness of the new-born child: hence it is always prudent to prevent by a ligature a loss of blood that would increase the debility.

The human ovum is very seldom detached entire, and never so without considerable danger; that is, the fœtus is not expelled with its membranes, and in the liquor amnii; for these are not, in general, expelled till a quarter of an hour, half an hour, or even a full hour after the delivery of the fœtus. When the uterus is completely emptied of the placenta and the membranes, its cavity becomes obliterated by the approximation of its sides; this organ, contracted on itself, sinks behind the pubes, its cervix closes, and this even impedes the delivery of the after-birth, when the latter is protracted too long. The parietes of the uterus, imbued with fluids, are thicker than in their natural condition; but they decrease in size, in consequence of the lochial discharge, and return to their wonted thickness.

When the labour is over, the uterus falls, as it were, asleep, and enjoys repose after painful exertion. The humours cease to be determined to that organ, towards which they are no longer directed by any irritation, and they flow towards the mammary glands, to supply the secretion of the fluid which is to nourish the new-born child.

CCXVIII. *Of twins.*—Though in the human subject the offspring is generally single, it is not uncommon for a woman to bring forth two children at once; it has even been calculated, that the proportion of twin cases to single births was as one to eighty. Indeed, there are cases of women who have brought three children at a birth. Haller calculates that the number of these last, compared to those of single births, is as one to seven thousand. The cases of four children at a birth are still less frequent; and if three children born at once seldom live long, the others, which, when born, are of the size of children at five months, cannot live. Only one or two instances are known of five children having been born at a birth: Haller, therefore, is guilty of exaggeration in saying that these cases are to the ordinary cases in the proportion of one to a million. I take no notice of the instances in which a greater number are said to have been delivered at once, because those cases are not well authenticated. In the case of twins, each child has its own umbilical cord, terminating sometimes in a separate, and sometimes in a single placenta. Both fœtuses are enveloped in one chorion, but each has a distinct amnion, and floats in a separate liquor amnii. It would be curious to know, whether in women who have had twins, as well as in animals, one should find two cicatriculæ, both in the same ovarium, or one in each. Twins are generally very like one another in features and dispositions.

The multiplicity of fœtuses in the same pregnancy is occasioned by the presence of several vesiculæ ready to be detached from the ovaria, and consequently ripe for fecundation. This multiplicity of offspring contributes very little to increase population, for they are in general less robust and strong, and not so capable of reproduction; they, besides, exhaust the strength of the mother, and their birth is often fatal to her. The number of children which a woman might bring into the world, from the period of puberty to the cessation of the menstrual discharge, would be much greater than it generally is, if no time were lost. Some women have been known to have twenty-four, thirty, thirty-nine, and even fifty-three children. A woman died in North America after having had five hundred children and grand-children, of whom two hundred and five survived her.

It is now well known, that the number of male children who are born exceeds in general that of the females. The difference in some countries is estimated at one in twenty-one, at a fourteenth, a twelfth, and sometimes,

though rarely, at a third. In all countries of the world, polygamy is, therefore, in direct opposition to the intentions of Nature and to the multiplication of the species : this is proved, in a most undeniable manner, by the loss of population in those countries in which this practice exists. The boys, more numerous than the girls during the early part of life, exposed afterwards to the dangers of war, of navigation, and occupied in laborious occupations, lead a more anxious life, and die in greater numbers ; so that the equilibrium is soon restored, and the least numerous portion of the human species at the cradle forms about two-thirds of it in old age, since we always see more women than men reach a very advanced period of life.

CCXIX. *Of superfœtations.*—The cases of fœtuses born with unequal degrees of developement, are not to be considered as superfœtations, but as twin cases. Thus, if in a case of twins, one fœtus is of its full size while the other is an embryo, whose size does not exceed that of a fœtus in the first month, it does not follow that their conception took place at different and distinct periods, but merely that, for some reason or other, one of the germs has been incapable of growth and developement.

To settle the question of superfœtations, one should know whether a woman, with a single uterus, is capable of conceiving two months after effective copulation. Haller is of opinion, that the cervix of the uterus is always open to the semen ; but how is the latter to reach the ovaria through the adhesions of the chorion to the uterus ? It appears easier, where the two conceptions are separated by a short interval : thus, the American woman mentioned by Buffon, who, in the course of one morning, had connexion with her husband and with a negro slave, bore two children of different colours. Hence, likewise, it sometimes happens, that one of twins is, by its features, a living testimony of adultery.

Two children born with an interval of some months between their births, cannot be considered as twins, though they may have existed some time together within the mother's womb. The possibility of such superfœtations is well proved ; they are ascribed to septa dividing the uterus sometimes into two cavities, merely because such an arrangement would explain, to a certain degree, how two conceptions might take place at some interval from one another ; for it has never been ascertained by actual dissection that any woman in whom such superfœtations took place had a double uterus.

CCXX. *Of suckling.*—Nothing is more generally known in physiology than the strict sympathy which subsists between the uterus and mammæ ; a connexion, in consequence of which these two organs are called into action at the same period of life, are evolved and cease to perform their functions at the same time, when woman becomes incapable of co-operating in the reproduction of the species. I shall not endeavour to account for this sympathy by ascribing it to the influence of the nervous system, or to the anastomosis of the epigastric with the internal mammary arteries—an anastomosis which is not uniform ; for, instead of inosculating with each other, these vessels frequently terminate in the recti muscles of the abdomen. But even though this anastomosis should exist as distinctly as it is often met with in some subjects, it would not account for this sympathy ; since the uterus and the mammæ often receive no branches from the epigastric and mammary arteries, and when they do they are exceedingly small. The breasts increase in size during pregnancy, but they are largest after delivery.

The new-born child, on being brought in contact with the breasts, applies its mouth to the nipple, and withdrawing its tongue, while with its lips it compresses the edges of the nipple, he sucks in the fluid, whose flow is facilitated by the erection of the lactiferous tubes. These ducts, from twelve to

fifteen in number, not only become enlarged when the nipple, which almost entirely consists of them, is elongated by being drawn out by the child; but, besides, being excited by its touch, they become affected with a certain degree of erection, and emit their fluid. This excretion, like that of other glands, is excited by the touch and the motion of the hands of the child on its nurse's breasts. The use of these gentle compressions is not so much to express the milk mechanically, as to excite the organ to excretion.

The irritation produced by the child on the nipple is the most powerful exciting cause of the determination of milk into the breasts; this irritation, or any other of the same kind, is sufficient to excite the secretion of milk, even under circumstances not provided for by Nature. It is thus that virgins have been enabled to suckle another mother's child; that young girls under the age of puberty have had so complete a secretion of milk, as to furnish a pretty considerable quantity of this fluid. There have been known men, in whom a long continued titillation of the breasts had determined such an afflux of the humours, that there oozed from them a whitish, milky, and saccharine fluid, not unlike the milk of a woman. The sucking of the new-born child is necessary to keep up the secretion of milk in the mammæ. It ceases to be formed in them when the child is committed to the care of a different nurse: the mammæ, at first turgid, soon collapse, especially if care have been taken to determine the fluids downwards by exhibiting gentle laxatives.

The erection of the breasts by titillation on the nipple, the spasmodic, and almost convulsive, action which follows this kind of excitement, may be carried so far as to produce an emission of the fluid to some distance. While its excretion lasts, women experience in their breasts an agreeable sensation; these parts are tense and swollen; they feel, as they express it, the milk rising; several feel a sensation of extension reaching to the axilla, to the arms and chest. The whole mass of cellular substance surrounding the breasts and extending to the neighbouring parts, partakes in their activity.

The breasts, themselves, consist, in great measure, of cellular substance; an adipose and lymphatic layer, of a certain thickness, covers the gland, which is divided into several lobes, and encloses it within its substance. They receive a number of nerves, but very few blood-vessels for their bulk.

Their structure appears almost wholly lymphatic: the vessels of this kind, after being distributed to the neighbouring glands, and especially to those of the axilla, penetrate into the breasts, in which their proportion, compared to that of the sanguineous vessels, is as eight to one. These lymphatic vessels, which enter in considerable numbers into the composition of the breasts, increase greatly in size in nurses; and when injected in this condition, it has been ascertained that several of them joined to form larger trunks, which going towards the nipple, contributed in forming what are called the *lactiferous tubes*. If the lymphatic vessels be immediately continuous with the excretory ducts of the breasts, there is reason to believe that it is these vessels which convey the materials of the fluid which they separate, especially if it be considered how small is the number of minute arteries which are distributed into their tissue, and what a disproportion there is between the calibre of these small vessels and the quantity of blood which the breasts supply. The opinion that the lymphatic vessels bring to the breasts the materials of the secretion of milk, is not in opposition to the laws of the circulation in the lymphatics: all who are acquainted with these laws, know that the course of the lymph, though in general from the circumference to the centre, is naturally liable to a number of aberrations or deviations, facilitated by the numberless anastomoses of these vessels.

CCXXI.—The granulated structure is not so apparent in the breasts as in the other glandular organs; hence they bear a greater resemblance to the lymphatic than to the conglomerate glands. The milk which they secrete has always been considered as very like the chyle, which it resembles in its white colour, its smell, and its saccharine taste. Like the chyle, it is the least animalised fluid, the sweetest, that on which the action of the organs produces the least effect, and that which preserves most the characteristic qualities of the food taken by the nurse.

It is well known, that instead of giving medicines to infants at the breast, we most frequently administer the medicine to the nurse; thus, the milk acquires purgative qualities, and acts on the bowels of the child, when the nurse has been purged.* The chyle is white and opaque only in those animals which suckle their young; in the others it is as transparent as lymph. (Cuvier.)

In the last place, if the arteries carried to the breasts the materials of their secretion, they ought to increase in size when these organs become twice, or even three or four times larger than natural; in the same manner that in open cancer, and in other similar affections, in which the determination of blood being increased, the calibre of the vessels is proportioned to them. Nothing, however, of the same kind occurs, whatever size the breasts may acquire from the presence of milk: their arteries preserve their almost capillary minuteness, as I had an opportunity of ascertaining, by injecting the mammæ of a woman twenty-nine years of age, who died in the second month of suckling, and whose breasts were remarkable for their size, and by the quantity of milk they were able to secrete.

Notwithstanding all these reasons, which made me formerly adopt the opinion of the celebrated Haller, who considers the milk as immediately extracted from the chyle, I own that it must be considered as hypothetical, and resting solely on probability. The impossibility of demonstrating anatomically the branches going from the mesentery to the breasts without communicating with the thoracic duct, gives still greater probability to the generally received opinion, which makes the milk, like all the other secreted fluids, with the exception of the bile, to be supplied by arterial blood. The passage of injections from the arteries into the lactiferous tubes, and the circumstance of blood having been drawn from an exhausted breast when the child has been allowed to suck too long, and lastly, analogy, leave no doubt of the true source of the fluid secreted by the mammæ.

The milk does not resemble chyle in every respect, though it may be considered as extracted from the food,† changed in its way to the mammæ by the glands through which it has passed, and especially by the action of the organs themselves. This action is so evident, that, as Bordeu observes, "there are women who seem to have no milk in their breasts, which are flaccid and empty; but as soon as the child excites them, they become distended, and the milk comes spontaneously." It is well known, and the same author has pointed it out, that women, cows, and the females of other animals, allow themselves more willingly to be sucked by a suckling that knows how to excite their sensibility, and to apply due irritation to the nipple; and that, on the contrary, they retain their milk when the suckling does not excite the sensation in which they feel pleasure. It is thought, in some countries, that serpents know how to tickle the teats of cows, and that these ani-

* This only takes place when such purgatives are used as are readily absorbed into the circulation.—*J. C.*

† "Lac utilis alimenti est superfluum."—GALENUS *de Usu Partium*, lib. vii. cap. xxii.

mals enjoy this excitement, and allow themselves to be sucked by these reptiles.

CCXXII. *Of the physical properties of milk, and of the chemical nature of this fluid.*—The quantity of milk is in general proportioned to that of the aliments, to the degree of their nutritious qualities, to their moist and farinaceous nature. Though it equals in weight about one-third of the quantity of food taken by the nurse, it may exceed that proportion, or may not come up to it. Its specific gravity, even when the milk is lightest, is greater than that of distilled water, and is always proportioned to its consistency. The latter quality is in an inferior degree in woman, but is greater in the cow, the goat, the ass, and the ewe. Its fluidity is intermediate between that of aqueous and oily liquids; its colour, its smell, and flavour, have something very peculiar, and by which it is easily recognised; in the last place, it is not exactly alike at different periods of the same milking. This is proved by the work of MM. Deyeux and Parmentier on milk, a work abounding in valuable observations, and which may be considered as the complete history of this animal fluid. They observed, that the milk first drawn from the cow is serous, that its consistency gradually increases, and that the richest milk is that which is obtained towards the end of milking, as if the fluid contained in the udder were affected by the laws of gravitation.

The milk, when exposed to the open air, in a vessel, becomes decomposed like the blood, and separates into three parts; the serum, the curd or cheesy part, and the fatty part or cream. The latter, which is lighter than the others, is always on the surface, and its quantity depends not only on the richness of the milk, but also on the extent of the surfaces by which it is in contact with the air; and this proves, as was first observed, by Fourcroy, that the oxygen of the atmosphere has some influence on its separation. The caseous part, which coagulates spontaneously, appears albuminous, and abounds in oxygen. MM. Parmentier and Deyeux consider it as the colouring matter of milk, and as giving to it its most characteristic properties. Lastly, the serum or whey, which alone constitutes the greatest part of this fluid, contains, besides a peculiar acid (*the lactic acid*),—which is formed when this substance is allowed to remain for some time,—a saccharine matter, which may be obtained by evaporation, and which, when crystallised in rhomboidal parallelopipeds, constitutes the sugar of milk, whose purity depends on the degree of care with which the process has been carried on. This sugar of milk contains, as Scheele first ascertained, while endeavouring, by means of the nitric acid, to convert it into the oxalic, a peculiar acid, in the form of a powder, difficult of solution, and to which he gave the name of saclactic acid. Milk may be considered as one of the most compound of the animal fluids, whose qualities are very valuable, and whose parts have but an imperfect affinity to each other; so that it is liable to spontaneous decomposition, which takes place very easily. This kind of emulsion contains but a small quantity of azote, so that it retains its vegetable character. Hydrogen, carbon, and oxygen, predominate in milk; in the last place, it contains several salts, amongst others, muriate of soda, muriate of potash, and phosphate of lime.*

The presence of the two last of these substances leads to the following considerations. Muriate of potash, as is observed by Rouelle, does not exist in the blood; the probability is, therefore, that it is not the blood which supplies the mammæ with the materials whence the milk is secreted, muriate of potash being found in greater quantity in milk than muriate of soda. These salts of potash, on the contrary, are found in considerable proportions in the

* See the chapter at the end of the Appendix, on the Chemical Constitution of the Secretions.

chyle, formed from vegetable substances; which would lead one to think that milk is furnished by the absorbent system. The phosphate of lime, which is found in smaller quantity in the urine of nurses, and which is wholly determined towards the mammæ, was absolutely necessary in a fluid which supplies nourishment to the new being, while the bones become indurated, and all the parts acquire solidity.

If we now wish to inquire into the causes which render suction necessary, and which subject the new-born child to this peculiar mode of nutrition, these causes will be found in the general weakness of its organs. The organs of digestion would have been incapable of extracting from the aliments their nutritive parts, these substances not having undergone the due degree of trituration, from the want of teeth and from the imperfect state of the other organs of mastication. It was of consequence, therefore, that the mother should perform this preliminary function, and that she should transmit the aliment ready digested.* It is not, however, to be imagined, that the milk passes, without undergoing any change, into the vessels of the child; the child digests the milk, and obtains from it in a short space of time, and without effort, a considerable quantity of nutritious particles, necessary to the rapidity of its growth.

The connexion between the mother and child is far from being broken at the period of birth; the relations between them, though not so close, are not less indispensable. Before birth, the vital power was so limited in the child, that it was necessary it should receive a fluid already animalised, and in a state to yield to the function of assimilation and nutrition. When the child has breathed, when its strength is increased, it may be intrusted with a greater share of the process; it is then sufficient that the aliment should have undergone the first degree of elaboration within the digestive canal. But it is not merely to assist in preparing its food, that the new-born child requires the aid of the mother; its lungs, which are delicate and imperfectly evolved, do not supply a due quantity of oxygen to the blood which circulates through them; the animal heat would be under what is required by the wants of life, if the mother did not make up for this deficiency by transmitting some of her own warmth. She folds her infant gently to her bosom, warms it with her breath, and by this kind of maternal incubation continues to cherish it with that calorific influence to which it was fully exposed while forming a part of herself. Besides, she feels for it, keeps it from danger, foresees its wants, and understands its language; and this very interesting intercourse takes place after the bonds of their physical communication are loosened, but it does not tear them asunder. The infant is, therefore, detached from the mother only by degrees, since it is only in proportion as it grows older that it acquires the means of an independent existence.

The secretion of milk in the breasts may be prevented by irritation in the uterus. If the labour have been difficult, if the woman have suffered a certain degree of injury, the irritation in the parts so affected prevents the determination of the fluids towards the mammæ. Hence, these organs collapse during puerperal fever; not that the milk flows back into the humours and becomes the cause of the complaint, but that the inflammation of the uterus prevents the fluids from flowing in their natural direction.

During the first few days after delivery, the parietes of the uterus discharge a fluid, at first bloody, then of a reddish colour, and, in the last place, mucous and whitish, termed the lochia.

CCXXIII. *State of the lungs and foramen ovale in some cases, &c.*—All the parts of the lungs are not distended with air, in the first inspirations of the

* *Lac est cibus exactè confectus.*—Galenus *de Usu Partium*, lib. vii. cap. xxii.

child after birth. Some of the lobes, which are harder and more compact, take some time to admit this fluid, and even sometimes altogether reject it. A child died twenty-one days after birth; the body was opened by Professor Boyer. On examining the lungs, he found that the posterior part of these organs was as hard and compact as in the fœtal state. The anterior part alone was distended, contained air, could be felt to crepitate, and floated in water. The heart was examined, to ascertain whether its structure was connected with the condition of the lungs, which depended on the want of power in the respiratory functions. The foramen ovale was found pervious, so that the blood could pass from the right into the left cavities of the heart, without flowing through the lungs. The child had been exceedingly languid during the whole of its short life; its skin was at times pale, at others livid. It was very difficult to keep it warm.

The child of Madame L**** died nine days after birth, with the same appearances. I opened the chest, and found the upper part of both lungs indurated and compact; the foramen ovale was quite pervious. This aperture is often closed very imperfectly, so that there remains, at the upper part of it, an opening, varying in size, which would enable a small quantity of venous blood to pass from the right into the left auricle, if these cavities did not contract at the same moment, and if the fluid which they contain did not present equal resistance on both sides. There are cases of persons in whom the foramen ovale remained pervious, and who, nevertheless, lived to a pretty advanced age. Their skin was purple and livid, all their moral and physical faculties feeble and torpid. It would be interesting to ascertain by dissection, whether in good divers, who can remain a long while under water without breathing, the foramen ovale is not imperfectly closed.

CHAPTER XII.

OF THE PERIODS OF LIFE, THE TEMPERAMENTS, THE VARIETIES, AND THE DISSOLUTION, OF THE HUMAN SPECIES.

CCXXIV. *Of infancy.*—The epidermis of the new-born babe thickens, the redness of the skin grows paler, the wrinkles are effaced, the soft down which covered the face falls and disappears, the buttocks swell out and soon conceal the opening of the rectum. During the first months of life, it seems to need nothing but nourishment and sleep. In the meanwhile the understanding is beginning to form, it looks fixedly at objects, and seeks to take cognisance of all the bodies that surround it. Confined at first to the uneasy sensations which it expresses by almost continual tears, its existence becomes less painful as it grows accustomed to the impressions of outward things upon its delicate organs. Towards the middle of the second month it becomes capable of agreeable sensations. If it feels them before that time, at least it is only then that it begins to express them by laughing.*

* At Herculis risus præcox ille et celerrimus, ante quadragesimum diem nulli datur.—Plin. *Hist. Nat.* præf. ad lib. viii.

CCXXV. *Of dentition.*—Towards the end of the seventh month,* the middle incisor teeth of the upper jaw cut through the substance of the gums: a little while after, the corresponding incisors of the lower jaw shew themselves; next, the lateral incisors of the upper jaw, afterwards those of the lower, then the cuspidati, in the same order. At the age of between eighteen months and two years, the small molar teeth appear, but in reversed order, those of the lower preceding those of the upper jaw. When these molar teeth have come through, the first dentition is complete; the life of the child is more secure: it was before very uncertain, since the calculations of the probable duration of human life shew, that a third of the children born at any given time die before the age of twenty-three months. Convulsions and diarrhœas are the most fatal accidents attending difficult dentition. To these twenty teeth are added two new grinders in each jaw, when the child has reached the end of his fourth year. These last will afterwards become the first large grinders. They differ from those that precede them in this, that they are to remain all life long, whilst the primitive or milk teeth are lost at seven years old, in the same order in which they appeared, and are replaced by new teeth, better formed and larger, excepting the small grinders, and with longer and more perfect roots. Towards the ninth year two new large grinders appear beyond the others. The child has then twenty-eight teeth, and dentition is complete; though between eighteen and thirty, and sometimes much later, the dentes sapientiæ, two to each jaw, shew themselves at the extremities of the alveolar processes.

The order observed in the successive cutting of the teeth is not so invariable but it is frequently inverted. A child ten years old, now under my care, cut the four first small grinders before the canine teeth. Dentition is, in this respect, like all other acts of the living economy—instability is its principal character. An attentive examination soon shews how irregularly those phenomena proceed, whether physiological or pathological, which appear the most to be subjected to calculable and determinate periods.†

This double range of successive teeth existed in the jaws of the fœtus. Each alveolar process, at that age of life, contains two sets of membranous vesicles, lying one over the other. Those which are to form the primitive teeth swell the first, a calcareous matter covers their surface and forms the body of the teeth, invading also the vesicle by which it is secreted; so that the growth of the tooth being completed, the membranous vesicle, in the parietes of which the dental vessels and nerves branch out, is found in the centre of its body, and adheres to the parietes of its internal cavity. The teeth are, then, secreted calcareous substances, or rather excreted by the dental vesicle: the vessels ramified in the parietes of this vesicle are prolonged into the osseous substance. This may at least be presumed, from the intimate adhesion of the membrane with the osseous matter. The teeth are possessed of, or participate in, the vitality of the system, and they increase by intussusception, although they cannot resist the effects of attrition, and are worn

* It would be very difficult to say why a tertian fever often terminates of itself when it has reached its seventh paroxysm, whilst a continued fever is judged of by critical evacuations, in seven, fourteen, or twenty-one days; why delivery happens at the end of nine months; why the first teething begins at seven months old, the second at seven years; why puberty shews itself towards the fourteenth year, and menstruation is repeated at determinate periods. Nature appears to subject herself, in all her acts, to certain periods; which observation may ascertain without any possibility of arriving at a knowledge of the causes of these phenomena, so easy to establish. Because their manifestation is correlative to certain numerical terms, we are not to put faith, like Pythagoras, in the power of numbers, and believe that the number 3, and the numbers 7 and 9, enslave all nature to their supreme influence. We find traces of this ancient error in all sciences, in all religions, even in those of enlightened nations.

† *See* "Erreurs Populaires," sec. edit. chap. iv. "*Des Années climatériques, et des Jours critiques dans les maladies.*"

down by it. The primary dental germs are connected with the secondary germs, or those which give origin to the teeth of the second dentition, by means of membranous prolongations, which are extended from the one set to the other, and which penetrate, by small foramina, the alveolar processes. It is through these openings,—*foraminula* of Sœmmering,—that the teeth of the second dentition pass: the germs of these are behind those of the first dentition, and the former are united to the latter, and pass to the alveolar margin, as now stated. It is not very difficult to say why the growth of the dental germs is successive; why, in the seventh year, the primitive teeth are detached and are replaced by others which have remained so long buried within the alveolar processes. The jaws grow in every direction, and consequently the alveolar processes increase their dimensions with the age of the individual. The primary teeth are insufficient to furnish the dental arches, and hence nature replaces them by means of a set which is of larger dimensions and more numerous. Dentition is like all other phenomena of the living economy; it is subject to endless varieties in its period and duration, &c. Thus, teeth of a third set have been known to be cut in very old people. There are instances, but they are very scarce, of children that have come into the world with two incisors in the upper jaw;* there are often supernumerary teeth, &c.

CCXXVI. *Of ossification.*—The process which goes on in the osseous system is not confined to the cutting and growth of the little bones which are attached to the two jaws. All other parts of the skeleton harden; osseous nuclei are formed in the centre of the cartilages, which hold the place of the short bones of the carpus and tarsus; the thickness of the cartilaginous substances which separate the epiphyses of the bodies of the long bones is diminished; the large bones grow and acquire solidity from the centre to the circumference. Those of the skull meet at their edges, their fibres cross and form the sutures; the cartilaginous spaces (*fontanels*), which were situated at the meeting of their edges and angles, disappear. The urine contains exceedingly little phosphate of lime, that salt being entirely taken up in the solidification of the bones.

About the middle of the second year, the bones have already acquired substance and solidity enough to support the weight of the body; the child can stand and walk. Before this time it would be hurtful to allow either the one or the other to be tried: the pillars of support, yet too flexible, would yield under the burden, and bend permanently in different directions. It is towards the head that the vital motions tend in infancy; accordingly, this part is the principal seat of the affections peculiar to this age,—affections in which it is often of use to procure local evacuations.

The organs of the senses, open to all sorts of impressions, receive them with ease; but if in early infancy sensation is easy, it is very transient, no doubt from the want of consistence in the cerebral organ. As it grows older, the mobility of the child is lessened without diminution of its susceptibility; and it is during the years that precede the boisterous season of puberty, that he enjoys, in the highest degree, the faculty of recalling things that have affected him—that his memory is most distinct and extended; but soon overpowered by imagination, roused up by the powerful reaction of the sexual organs on the brain, it ceases to have the same exactness.

* Louis XIV. was born in this condition. Baudelocque observes, that the evolution of some teeth before birth is not always connected with an extraordinary growth of the infant, nor is it always a presage of a stronger constitution. He endeavours to prove this by several examples; these, however, may be regarded as exceptions only from the general, and, we think, correct, opinion on the subject.—*J. C.*

CCXXVII. *Of puberty.*—Sex, climate, manner of life, have great influence on the earlier or later manifestation of the phenomena of puberty. Women reach it one or two years before men; the inhabitants of southern long before those of northern countries. Thus, in the hottest climates of Africa, Asia, and America, girls arrive at puberty at ten, even at nine years old; but in France, not till twelve, fourteen, or fifteen; whilst in Sweden, Russia, and Denmark, the menstrual discharge, the most characteristic mark of puberty, is from two to three years later.

The male is known to be capable of generation, and that he begins to live the life of the species, by the emission of prolific semen, and the change of voice, which becomes fuller, more grave, and sonorous: the chin becomes covered with beard, the genitals with hair, and they attain rapidly their full size. The whole body grows: the general characters which distinguish the two sexes, and which are so obscure before puberty that they may often be mistaken, become very decided, and can no longer be confounded.

By all these signs of strength and virility, woman, urged by desires which may be termed wants, recognises the being capable of gratifying them. The change of voice is the most certain of the indications of male puberty. It depends, as the following observations shew, on the developement of the vocal organs, which constantly accompanies that of the sexual parts.

CCXXVIII. A boy, aged fourteen, died in the year 1799, at the Hôpital de la Charité. On opening the larynx, I was surprised to see it so small, and especially the glottis, which was not above five lines in its anterio-posterior diameter, and about a line and a half in its transverse diameter, where its dimensions are greatest: an observation that must not be omitted is, that he was very tall, but that the developement of the genital organs was as backward as of the vocal. I have repeated the same observation on subjects further from the age of puberty—I have extended my researches to those who had passed it; and I have obtained, as a general result, that between the larynx and the glottis of a child of three or of twelve, the difference of size is very inconsiderable, and cannot be estimated by the height of the figure.

That, at the epoch of puberty, the organ of the voice enlarges rapidly, and that, in less than a year, the opening of the glottis increases in the proportion of five to ten; that its extent is thus doubled both in length and breadth.

That these changes are less remarkable in women, whose glottis increases in the proportion only of about five to seven; that in this respect they still resemble children, as the tone of their voices would lead us to suppose.

These differences in the size of the glottis account for the danger which, in children, accompanies the croup; for, suppose an opening of a line and a half in width, the edges of which are covered with a membrane of coagulable lymph, the opening will be entirely stopped: it would be only narrowed if its width were double; a sufficient space would remain free from the passage of the air. This supposition, which I have employed to make myself understood, is only the expression of the truth, since anatomical inspection shews that the glottis in adults is double the size it is before puberty.

CCXXIX. *Of menstruation.*—The symptoms by which puberty is known in women are not less remarkable. The swelling of the genital organs straightens the opening of the canals that make part of them. The breasts become enlarged, and form, at the fore-part of the thorax, marked projections. Further, there comes on a discharge of blood, which takes place every month, from the vessels of the womb, and which is known by the name of the menstrual discharge, or menses. This periodical evacuation declares itself in most women by all the symptoms that indicate fulness of blood, as,

spontaneous lassitude, heat, and flushings in the face; and by others, which shew a direction of the humours towards the uterus, and a local plethora of that organ, as pains in the kidneys, and a certain itching of the parts. The first eruption puts an end to this state, which in many may be considered as real disease. A pure red blood flows, in more or less abundance, for some days, the general heaviness goes off, and the woman feels herself relieved.

I shall not now speak of the many deviations incident to the menstrual discharge, and which must be considered as real diseases. Thus, the uterine discharge has been known to be supplied by bleeding from the nose, hæmoptysis, melæna; sometimes by unusual evacuations of blood from the eyes, ears, the fore-finger, or from ulcerated surfaces over different parts of the body.

It is easily conceived, that the different parts of the sanguineous system may supply each other's place, and that the bloody secretion in which menstruation consists, in failure of the internal surface of the uterus, may be carried on by another part equally provided with capillary vessels; but that similar deviations may take place for the fluids secreted by the conglomerate glands—as urine, bile, saliva—is difficult to believe, notwithstanding the many testimonies and authorities that may be brought in support of this opinion.

The fluids are not in existence before the work of secretion: the urine, retained in the bladder and in the uterus; the bile, accumulated in the gall-bladder and the hepatic ducts, after it has been prepared by the peculiar action of the liver,—may, it is true, from absorption by the lymphatic vessels, be carried into the blood, and produce there a diseased urinary or bilious diathesis—occasion an irritation and derangement, after which the humour of the cutaneous perspiration and of the sweat, and the saliva itself, will exhibit some of the qualities of the humour retained, and introduced by the absorbents into the circulation. The blood, contaminated by the admixture of a certain quantity of urine, may purify itself by various emunctories, by urinous vomitings and sweats; but that urine may, like the menstrual blood, come out at the eyes, the ears, or the navel, except in cases of urinary umbilical fistula—that one whose urinary discharge by the urethra is not interrupted, may spontaneously vomit it,—is what no man who has any sound notions of physiology will believe; and yet it is related, with full details, in a late work, where these errors are found in the midst of many interesting researches on various points of physiological chemistry. I have myself seen the woman whose urine has been so well analysed by Dr. Nysten, when the clinical professor of medicine at Paris obliged her to submit to a severe but necessary examination, and I am astonished that well-informed men should so long have given credit to such gross impostures. The reader will, I hope, excuse this long digression, for the sake of its importance. Literary criticism is now carried on with such partiality, that no journalist, in praising what is justly praiseworthy in the valuable work of Dr. Nysten, has pointed out the imposture of which he was the dupe.

At first irregular, the menstrual discharge assumes regularity, is repeated every month, and lasts from two days to a week, with evacuation of from three ounces to a pound of blood every time. Women of sanguine temperament, robust and libidinous, are those whose menses last longest and flow most copiously. The blood is arterial, red, and has not, in a healthy woman, any of the pernicious qualities which have been ascribed to it.

During the whole time of menstruation, women are weaker, more delicate, more susceptible of impressions; all their organs partake, more or less,

in the affection of the uterus; and it is not difficult to an observer of any practice to discern the state, not merely by the state of the pulse, but by the change of the countenance and tone of the voice. Women then require very careful management. An improper blood-letting, a purge, or any other remedy untimely administered, may suppress the discharge, and occasion the most serious affections. Climate evidently influences its duration and quantity, since in Africa it flows almost continually, whilst in Lapland it takes place only two or three times a year.

I shall not dwell upon the different explanations that have been given of this phenomenon. Some have ascribed it to the oblique position of the uterus, without considering, that upon their principle menstruation should take place from the soles of the feet. Richard Mead believed that it depended on the influence of the moon over the female system; but why is it not then subjected to the lunar phases? Those who have found the cause of it in plethora, general or local, have, if we admit their explanation, only changed the difficulty; for then, we must ask, what are the causes of this plethora? But if this opinion had any ground, nervous women, with a small quantity of blood in their system, ought not to menstruate; and yet they do so, plentifully. Must we ascribe menstruation to an acquired habit?

Is the problem resolved, by saying that all the secretory organs of women are too weak to evacuate the superfluity of humours, which would require for them a new emunctory? But is not this taking the effect for the cause? Does not this smaller quantity of fluids proceeding from the blood, arise from the purification which the blood undergoes in the uterus? Let it be remarked, in the meantime, that this periodical discharge seems to exempt the sex from many inconveniences from which ours suffers, such as gout, stone, and gravel, so unfrequent with them, and so common with us. Nor can we avoid recognising in this discharge a utility relative to conception: does it not seem to dispose the uterus to that function?* (CCIV.) Was it not requisite that this organ should be accustomed to receive a great quantity of blood, that pregnancy, which calls for this afflux, might not be injured, by bringing on a sudden change in the system and the whole of the vital functions?

Menstruation is suspended during pregnancy; it is so during the first month of suckling; though this rule admits of many exceptions. Its cessation, in our climate, is from the fortieth to the fiftieth year; sometimes before, seldom later; though I have now before me the instance of a woman of seventy who has not yet ceased to menstruate; a fact which, after all, is nothing more surprising than that of menstruation beginning at an early period of life. When menstruation ceases, the breasts collapse, plumpness goes off, and the skin shrivels and loses its softness, colour, and suppleness. This cessation is the cause of a great many diseases which break out at this season of life, called the turn of life, and are fatal to many women; but then, it is observed, that when this period is past, their life is more secure, with greater hope of prolonging it, than a man has at the same age.

CCXXX. *Of manhood.*—To youth succeeds manhood, which may be considered as beginning from the twenty-first to the twenty-fifth year. Then all increase of the body in height is at an end. The processes are completely united to the body of the bones, but still growth goes on in other dimensions. All the organs acquire remarkable hardness, solidity, and consistency. It is the same with the intellectual and moral faculties. To the empire of imagination succeeds that of judgment. Man is capable of fulfilling all the du-

* The greater part of female quadrupeds have the parts of generation bathed in a reddish lymph during the time of being in heat.

ties of family and society. This period of life, to which we give the name of mature age, extends to the fiftieth or fifty-fifth year for men: it scarcely goes begond the forty-fifth for women, with whom it begins also a little sooner. During this long interval, men enjoy the whole plenitude of their existence.

Although in general it is not difficult to distinguish at first sight a man of twenty-five from one of fifty, the differences which mark them, depending on the quantity and colour of their hair, and on their muscular strength, are neither many nor very essential.

Let us avail ourselves of this age, during which the characters of the human species, merely sketched in childhood and youth, take a more defined and lasting form, to trace the features of individuals and of races.

CCXXXI. *Of temperaments and idiosyncrasies.*—We give the name of *temperaments* to certain physical and moral differences in men, which depend on the various proportions and relations among the parts that make up their organisation, as well as upon different degrees in the relative energy of certain organs. There is, besides, in each individual, a mode of existence which distinguishes his temperament from that of any other, to whom, however, he may bear great resemblance. We express by the term *idiosyncrasy* these individual temperaments, the knowledge of which is of no small importance in the practice of medicine.

The predominance of any particular system of organs modifies the whole economy, impresses striking differences on the results or the organisation, and has no less influence on the moral and intellectual, than on the physical faculties. This predominance establishes the temperament; it is the cause, and constitutes its essence.

CCXXXII. *Of the sanguine temperament.*—If the heart, and the vessels which carry the blood through every part, are of predominant activity, the pulse will be sharp, frequent, regular, the complexion ruddy, the countenance animated, the shape good, the form softened though distinct, the flesh of tolerable consistence and moderate plumpness, the hair fair and inclining to chestnut; the nervous susceptibility will be lively, and attended with rapid *successibility*, that is to say, that being easily affected by the impressions of outward objects, men of this temperament will pass rapidly from one idea to another; conception will be quick, memory prompt, the imagination lively; they will be addicted to the pleasures of the table and of love, will enjoy a health seldom interrupted by disease, and all their diseases, and these slight, modified by the temperament, will have their seat principally in the circulatory system, (*inflammatory fever or angeioténique, phlegmasia, acute hæmorrhage*), and will terminate, when moderate, by the mere force of nature, and require the use of the remedies called antiphlogistic, among which bleeding is the chief. The ancients applied the name of *sanguine* to this disposition of body; they considered it as produced by the combination of warmth and moisture, and had very correctly perceived that it existed in the young of both sexes, was heightened by the spring, the season which has been justly compared to youth, calling that age the spring-time of life.

That the specific characters of the temperament I have just described may shew themselves in all their truth, it is requisite that the moderated developement of the lymphatic system coincide with the energy of the sanguineous system, so that these two sets of vascular organs may be in true equipoise. The physical traits of this temperament are to be found in the statues of Antinous and the Apollo of Belvidere. Its moral physiognomy is drawn in the lives of Mark Antony and Alcibiades. In Bacchus are found both the forms and the character. But why seek amongst the illustrious men of antiquity, or among its gods, the model of the temperament I have been describing,

whilst it is so easy to find it among the moderns? No one, in my opinion, exhibits a more perfect type of it than the Marshal Duke of Richelieu, that man so amiable, fortunate, brave in war, light and inconstant, to the end of his long and brilliant career.*

Inconstancy and levity are, in fact, the chief attribute of men of this temperament: excessive variety appears to be to them a necessity as much as an enjoyment: good, generous, feeling, quick, impassioned, delicate in love, but fickle, disgust in them follows close upon enjoyment; meditating desertion in the midst of the most intoxicating caresses, they make their escape from beauty at the very moment she thought to have bound them by indissoluble chains.† In vain he whom nature has endowed with a sanguine temperament will think to renounce the pleasures of the senses, to take fixed and lasting likings, to attain by profound meditation to the most abstract truths; mastered by his physical dispositions, he will be for ever driven back to the pleasures from which he flies, to the inconstancy which is his lot; more fitted to the brilliant productions of wit, than the sublime conceptions of genius.‡ His blood, which a vast lung impregnates plentifully with atmospherical oxygen, flows freely in very dilatable canals; and this facility in the distribution and course of the humour is at once the cause and the image of the happy dispositions of his mind.

If men of this temperament apply themselves, from circumstances, to labours which greatly exert the organs of motion, the muscles, plentifully supplied with nourishment, and disposed to acquire a developement proportioned to that of the sanguineous system, increase in bulk, the sanguineous temperament undergoes a great modification, and there results from it the muscular or athletic temperament, conspicuous by all the outward signs of vigour and strength. The head is very small, the neck sunk, especially backward, the shoulders broad, the chest large, the haunches solid, the intervals of the muscles deeply marked.

The hands, the feet, the knees, all the articulations not covered by muscles, seem very small; the tendons are marked through the skin which covers them; the susceptibility is not great: feeling dull and difficult to rouse, the athletic surmounts all resistance when he has once broken from his habitual tranquillity. The Farnese Hercules exhibits the model of the physical attributes of this particular constitution of body; and what fabulous antiquity relates of the exploits of this demi-god, gives us the idea of the moral dispositions that accompany it. In the history of his twelve labours, without calculation, without reflection, and as by instinct, we see him courageous because he is strong, seeking obstacles to conquer them, certain of overwhelming whatever resists him; but joining to such strength so little subtlety, that he is cheated by all the kings he serves, and all the women he loves. It would be difficult to find in history the example of a man who has combined

* See his Memoirs, 6 vols. 8vo.

Voltaire has painted his character with superior ability in many verses addressed to him:

Rival du conquérant de l'Inde,
Tu bois, tu plais, tu combats, &c.

† The history of Henry IV., of Louis XIV., of Regnard, and of Mirabeau, proves that, to the extreme love of pleasure, sanguine men join, when circumstances require it, great elevation of thought and character; and can bring into action the highest talents in every department.

‡ I have just met with an assertion in a gazette which is at least singular. All the world knows, says the journalist, that Newton was sanguine; and this proves clearly, he adds, that temperaments have no influence on the intellectual powers. I would ask the journalist where he has discovered that Newton was sanguine? The few details which biographers have preserved on the physical temperament of this illustrious philosopher, lead us to believe that his temperament was the melancholic, which is very frequently met with in England. I will not dare to pronounce absolutely on subjects on which we can attain only a certain degree of probability; but if Newton had been sanguine, he would not have carried his maidenhead with him to the grave, at the age of fourscore, as it is affirmed he did.

with the physical powers which this temperament implies, distinguished strength of the intellectual faculties. For excelling in the fine arts and in the sciences, there is need of exquisite sensibility,—a condition absolutely at variance with much developement of the muscular masses.

CCXXXIII. *Of the bilious temperament.*—If sensibility, which is vivid and easily excited, can dwell long upon one object; if the pulse is strong, hard, and frequent, the sub-cutaneous veins prominent, the skin of a brown, inclining towards yellow, the hair black, moderate fulness of flesh, but firm, the muscles marked, the form harshly expressed—the passions will be violent, the movements of the soul often abrupt and impetuous, the character firm and inflexible. Bold in the conception of a project, constant and indefatigable in its execution, it is among men of this temperament we find those who, in different ages, have governed the destinies of the world: full of courage, boldness, and activity, all have signalised themselves by great virtues or great crimes, and have been the terror or admiration of the universe. Such were Alexander and Julius Cæsar, Brutus, Mahomet, Charles XII., the Czar Peter, Cromwell, Sixtus V., Cardinal Richelieu.

As love is in the sanguine, so ambition is in the bilious the governing passion. Observe a man, who, born of an obscure family, long vegetates in the lower ranks. Great shocks agitate and overthrow empires: at first a secondary actor in those great revolutions which are to change his destiny, the ambitious man hides his designs from all, and by degrees raises himself to the sovereign power, employing, to preserve it, the same address with which he possessed himself of it. This is, in few words, the history of Cromwell, and of all usurpers.*

To attain to results of such importance, the profoundest dissimulation and the most obstinate constancy are equally necessary; these are, further, the most eminent qualities of the bilious. No one ever combined them in higher perfection than that famous pope who, slowly travelling on towards the pontificate, went for twenty years stooping and talking for ever of his approaching death, and who, at once, proudly rearing himself, cries out, "I am pope!†" petrifying with astonishment and mortification those whom his artifice had deceived into his party.

Such, too, was Cardinal Richelieu, who raised himself to a rank so near to the highest, and was able to maintain himself in it: feared by a king whose authority he established—hated by the great, whose power he destroyed, haughty and implacable towards his enemies, ambitious of every sort of glory, &c.‡

The historians of the time inform us, that this celebrated minister shewed all the customary signs of the bilious temperament. Gourville tells us, that he was all his life subject to a very troublesome hæmorrhoidal discharge.||

This temperament is further characterised by the premature developement of the moral faculties. Scarcely past their youth, the men I have named projected and carried into execution enterprises which would have been sufficient for their fame. An excessive developement of the liver, a remarkable superabundance of the biliary juices, most commonly accompanying this constitution of body, in which the vascular and sanguineous system enjoys the greatest energy, to the prejudice of the cellular and lymphatic system,—the ancients gave the name of *bilious*. The diseases to which those dis-

* *Vie d'Olivier Cromwell, par Jeudy Dugour*, 2 vol. 18mo.

† *Vie de Sixte Quint*, 2 vol. in 12mo.

‡ See his character, drawn with as much truth as eloquence, by Thomas, in the last edition of his *Essai sur les Eloges*.

|| *Mémoires de Gourville.*

tinguished by it are subject, involve, in fact, either as their principal characteristic, as accessary circumstances, or as complication, the derangement of the action of the hepatic organs, joined to changes of composition in the bile. Among the remedies directed against this sort of diseases, evacuants, and especially emetics, are the best.

If all the characteristics assigned to the bilious temperament are carried to the highest degree of intensity, and to this state is added great susceptibility,—men are irascible, impetuous, violent on the slightest occasions. Such Homer describes Achilles and some others of his heroes.

CCXXXIV. *Of the melancholic temperament.*—When to the bilious temperament is added diseased obstruction of any one of the organs of the abdomen, or derangement of the functions of the nervous system, so that the vital functions are feebly or irregularly performed, the skin takes a deeper hue, the looks become uneasy and gloomy, the bowels sluggish, all the excretions difficult, the pulse hard and habitually contracted. The general uneasiness affects the mind ; the imagination becomes gloomy, the disposition suspicious. The exceedingly multiplied varieties of this temperament, called by the ancients the *melancholic ;* the diversity of accidents that may bring it on, such as hereditary disease, long grief, excessive study, the abuse of pleasures, &c. justify the opinion which Clerc has proposed in his natural history of man in a state of disease, where he considers the melancholic temperament less as a primitive and natural constitution, than as a diseased affection hereditary or acquired. The characters of Lewis XI. and Tiberius leave nothing wanting for the moral determination of this temperament. Read, in the Memoirs of Philip de Commines, and in the Annals of Tacitus, the history of these two tyrants, fearful, perfidious, mistrustful, suspicious, seeking solitude by instinct, and polluting it by all the acts of the most savage atrocity and the most ungoverned debauch. Distrust and fearfulness, joined to all the disorders of imagination, compose the moral character of this temperament. The passage in which Tacitus paints the artful conduct of Tiberius, when he refuses the empire offered him after the death of Augustus, may be given as the most perfect model of it.*

As Professor Pinel very justly observes, in his treatise on insanity, the history of men celebrated in the sciences, letters, and arts, has shewn us the melancholic under a different light : endowed with exquisite feeling and the finest perception, devoured with an ardent enthusiasm for the beautiful, capable of realising it in rich conceptions, living with men in a state of reserve bordering upon distrust, analysing with care all their actions, catching in sentiment its most delicate shades, but ready in unfavourable interpretations, and seeing all things through the dingy glass of melancholy.

It is extremely difficult to delineate this temperament in a general or abstract manner. Though the ground-work of the picture remains always the same, its numerous circumstances give room for an infinite number of variations. It is better, therefore, to have recourse to the lives of illustrious men who have exhibited it in all its force. Tasso, Pascal, J. J. Rousseau, Gilbert, Zimmerman, are remarkable, among many others, and deserve, by their just celebrity, to fix our consideration. The first, born in the genial climate of Italy—proscribed and unhappy from his childhood—author, at twenty-two years old, of the finest epic poem the moderns can boast of—was seized, in the midst of the enjoyments of premature glory, with the most violent and most inauspicious love for the sister of the Duke of Ferrara, at whose court he lived—an extravagant passion, which was the pretext for the most cruel persecutions, and which followed him to his death : this took place towards the

* *Versæ inde ad Tiberium preces, &c.*—CORN. TACIT. *Annal.* lib. i.

thirty-second year of his age, on the eve of a triumphal pomp which was prepared for him in the capitol.

The author of the Provincial Letters and of the Thoughts, enjoying, like Tasso, a premature celebrity almost on quitting childhood, was led to melancholy, not, like him, by the crosses of unhappy love, but by a violent and overpowering terror, which left in his imagination the sight of a gulf for ever open at his side—an illusion which left him only at his death, eight years after the accident.*

No one, perhaps, has ever shewn the melancholic temperament in a higher degree of energy than the philosopher of Geneva. To be convinced of it, it is enough to read with attention certain passages of his immortal works, and especially the two last parts of his Confessions, and the Reveries in the Solitary Walker: tormented with continual distrusts and fears, his fruitful imagination represented to him all men as enemies. If you believe him, the whole human race is in league to do him mischief—"*kings and nations have conspired together against the son of a poor watchmaker*;" children and invalids are brought in to execute these dreadful plots. But let us leave him to speak for himself, the most eloquent and the most unfortunate man of the eighteenth century. "Here then I am, alone upon the earth, without brother, neighbour, friend, without society but myself: the most sociable and the most loving of men has been proscribed by them with unanimous consent." This is the beginning of the first walk; further on he adds, "Could I believe that I should be held, without the smallest doubt, for a monster, a poisoner, an assassin; that I should become the horror of the human race, and the game of the rabble; that all the salutation of those that passed by me would be to spit upon me; that a whole generation would amuse itself, with unanimous consent, in burying me alive?" It is idle to multiply quotations in speaking of the works of a philosopher who, in spite of his errors, will for ever be the delight of all those who love to read and to think.

The history of J. J. Rousseau, like that of all the melancholics who have distinguished themselves in literature, shews us genius struggling with misfortune; a strong soul lodged in a feeble body; at first gentle, affectionate, open, and tender, but soured by the sense of an unhappy condition, and of the injustice of men. Till the time when, impelled by the desire of fame, Rousseau sprang forward in the career of letters, we see him endowed with a sanguine temperament, acting with all the qualities belonging to it: gentle, loving, generous, feeling, though inconstant, his fertile imagination shews him nothing but gay images, and in this illusion of happiness he lives on agreeable chimeras; but gradually undeceived by the hard lessons of experience—afflicted, in the depth of his heart, with his own wretchedness and the wrongs of his fellow-creatures,—his bodily vigour wastes and decays, with it his moral nature changes, and he may be referred to as the most striking proof of the reciprocal influence of the moral on the physical, and the physical on the moral part of our being.† His history is a proof, beyond

* He died at 39. See his life by Condorcet.

† I have no doubt that the influence of the physical organisation on the intellectual faculties is so decided, that we may regard as possible the solution of the following problem, analogous to that with which Condillac concludes his work on the origin of human knowledge:—

The physical man being given, to determine the character and extent of his capacity, and to assign, consequently, not only the talents he possesses, but those he is capable of acquiring.

The profound meditation of the work of Galen (*quod animi mores corporis temperamenta sequantur*); the perusal of Plutarch's Lives of Illustrious Men, and of the other biographers and historians of ancient and modern times; of the Eulogies of Fontenelle, Thomas, d'Alembert, Condorcet, Vicq-d'Ayzr, &c.; and the study of the medico-philosophical works of Haller, Cullen, Cabanis, Pinel, Hallé, who have modified and enriched the ancient doctrine of temperaments, will be of great avail in the search after this solution. "Philosophy," cries an eloquent writer, in the noble enthusiasm which seizes him at the sight of the riches accumulated by Fontana, in the Anatomical Museum in

reply, that the melancholic temperament is less a peculiar constitution of the body than a real disease, of which the degrees may infinitely vary, from a mere originality of character to the most decided mania.

Gilbert arrived at Paris with the germs of talents fitted for that great theatre. Poor, and rebuffed by those on whom he had built his hopes, he mixed in the ranks of their detractors, and soon signalised himself among the most formidable, by a vigour worthy of a better cause. Persecuted without respite by want, the mortifying sight of the happiness which his enemies enjoyed, and to which he believed himself called, led him on to a state of perfect madness. He believed himself persecuted by the philosophers, who wanted to rob him of his papers: to save them from the imagined rapacity, he locked his manuscripts in a press, and swallowed the key. It stuck at the entrance of the larynx, stopped the passage of the air, and suffocated the patient, who died at the Hôtel-Dieu, after three days of the most cruel suffering.*

Zimmerman, early exhausted by study, already a physician of celebrity at an early age, lived in solitude, with an ardent imagination joined to the highest susceptibility: abondoned to himself, devoured with the thirst of glory, he gave himself up to labour in excess, published his treatise on Experience, and the work on Solitude, so deeply imbued with the colouring of his soul. Forced from the solitude he loved, he carried into the courts to which his reputation called him an inexhaustible store of bitterness and sadness, which, political events supervening, brought to greater excess: arrived, at length, gradually at the last term of hypochondria, he died beset with pusillanimous fears, worthy of all eulogium and all regret.†

CCXXXV. *Of the pituitous or lymphatic temperament.*—If the proportion of the fluids to the solids is too great, this superabundance of the humours, which is constantly in favour of the lymphatic system, gives to the whole body considerable bulk, determined by the developement and repletion of the cellular tissue. The flesh is soft, the countenance pale, the hair fair, the pulse weak, slow, and soft, the forms rounded and without expression, all the vital actions more or less languid, the memory treacherous, the attention not continuous. Men of this temperament, to which the ancients gave the name of *pituitous*, and which we should call *lymphatic*, because it depends really on the excessive developement of this system, have, in general, an insurmountable inclination to sloth, averse alike to labours of the mind and body: accordingly, we are not to wonder if we find none of them among Plutarch's illustrious men. Little fitted for business, they have never exercised great empire over their fellow-creatures; they have never changed the face of the globe by their negotiations or their conquests. One of the friends of Cicero,

Florence, "Philosophy has been in the wrong, not to descend more deeply into physical man; there it is that the moral man lies concealed; the outward man is only the shell of the man within."—DUPATY, *Thirty-third Letter on Italy.*

* His life would have been preserved if the cause of his illness had been understood, which he indicated himself by repeating for ever, "the key chokes me." His state of madness made this pass for the words of a madman; but on opening his body, the key was found, of which the ward part was fixed at the entrance of the larynx: it would have been easy to draw it out, by putting a finger down the throat.

This unfortunate young man expressed, a few days before his death, the melancholy state of his soul, in stanzas most touchingly mournful: this is one, full of interest and simplicity:—

Au banquet de la vie infortuné convive,
Je parus un jour, et je meurs;
Je meurs, et sur ma tombe, où lentement j'arrive,
Nul ne viendra verser des pleurs.

† See his Eulogium, by Tissot; it is at the beginning of the last edition of the Treatise on Experience in Medicine. It there appears how deeply he was affected by the French revolution, of which he foresaw, with a sort of prophetic spirit, the disastrous consequences to his own country.

Pomponius Atticus, whose history Cornelius Nepos has left us, conciliating to himself all the factions which tore the Roman republic to pieces in the civil wars of Cæsar and Pompey, may be given as the model of it. Among the moderns, the easy Michel Montaigne, all of whose passions were so moderate, who reasoned on every thing, even on feeling, was truly pituitous. But in him the predominance of the lymphatic system was not carried so far but that he joined to it a good deal of nervous susceptibility. In the pituitous, from the excess of watery particles in the fluid which should carry every where heat and life, the circulation goes on slowly, the imagination is weak, the passions languid; and from this moderation of the desires spring, on many occasions, those *virtues of temperament*, which, to say it by-the-by, should not supply their possessors with matter of quite so much self-complacency.

CCXXXVI. *Of the nervous temperament.*—This property, by which we are more or less sensible to impressions on our organs, weak in the pituitous, almost nothing in athletes, moderate in those of sanguine temperament, rather quick in the bilious, constitutes by its excess the nervous temperament;—it is seldom natural or primitive, but commonly acquired, and depending on a sedentary and too inactive life, on habitual indulgence in sensuality, on the morbid action of the brain, promoted by reading works of imagination, &c. This temperament shews itself in the emaciation, in the smallness of the muscles (which are soft, and, as it were, in an atrophy), in the vivacity of the sensations, in the suddenness and mutability of the determinations and judgments. Nervous women, whose wills are absolute but changeable, with excess of sensibility, frequently exhibit it with all these characteristics. Often, however, they have something of good looks, the extreme preponderance of the nervous system still allowing a moderate developement of the lymphatic. Spasmodic affections are not uncommon amongst them; and when it is observed that, on the other hand, the athletic constitution, directly opposite to the nervous temperament, predisposes to tetanus, may we not say, that the two extremes meet, or produce the same effects?

Anti-spasmodics are employed with success in the treatment of their diseases, which partake always, more or less, of the temperament. Stimulants, on the contrary, are very suitable to those of a pituitous or lymphatic temperament. The nervous temperament, like the melancholic, is not so much a natural constitution of the body as the first stage of a disease. This temperament, like the nervous affections which are the result of it, has never shewn itself but among societies brought to that state of civilisation in which man is the farthest possible from nature. The Roman ladies became subject to nervous affections only in consequence of those depraved manners which marked the decline of the empire. These affections were extremely common in France during the eighteenth century, and in the times preceding the fall of the monarchy. Of that epoch are the works of Wytt, Raulin, Lorry, Pomme, &c. on nervous affections. Tronchin, a Genevese physician, acquired great wealth and reputation by the treatment of these diseases. His whole secret consisted in exercising to fatigue women habitually inactive, keeping up their strength at the same time by simple, healthy, and plentiful food. The two most remarkable men of the eighteenth century, Voltaire and the great Frederick, may be given as instances of the nervous temperament; and the history of their brilliant and agitated life shews sufficiently how much the circumstances in which they lived contributed to develope their native dispositions.

I shall finish this article on temperaments by observing, that in truth we bring with us into the world these particular dispositions of body; but that

from education, manner of life, climate, acquired habits, they are altered or altogether changed. Further, it is exceedingly rare to find individuals who shew in their purity the characteristics assigned to the different temperaments: the descriptions given are drawn from an assemblage of individuals much resembling one another. Their characters are pure abstractions, which it is difficult to realise, because all men are at once sanguine and lymphatic, &c. In this instance, physiologists have imitated the artist, who united in the image of the goddess of beauty a thousand perfections, which he saw separate in the most beautiful women of Greece.*

It is an observation, that the sanguine constitution is directly opposed to the melancholic, and never combines with it; that it is the same with the bilious and lymphatic: though it may happen that a man, sanguine in youth, shall become melancholic after a lapse of time; for, as I have said before, man never remains such as he came from the hands of Nature: fashioned by all that surrounds him, his physical qualities, at different periods of his life, are as much changed as his character.

Of all the causes that can modify the constitution of man, and which will even change completely the nature of his original dispositions, there is none more powerful than the long-continued action of air, water, and residence, as the father of medicine has said. Climate, in fact, exerts upon the temperament the most marked influence. Thus, the bilious temperament is that of the greater part of the inhabitants of southern countries; the sanguine that of the nations of the north; the lymphatic constitution reigns, on the contrary, in cold and moist countries like Holland. We have seen in what manner the athletic, melancholic, and nervous temperament grows out of our habits of life; let us now endeavour to appreciate the power of climate over the constitution of the greater part of mankind.

It is known that the influence of heat in the production of bilious diseases is such, that after having been extremely prevalent during the summer, they disappear, or at least become much less frequent, in the autumn. A notable increase of perspiration never takes place without a proportional diminution in the quantity of the secretions with which the alimentary mucous surfaces are moistened. Now, when the gastric and intestinal juices are less abundant, the bile, being mixed with a smaller quantity of these fluids, irritates more the intestinal surfaces; the digestive powers languish, and there is an approaching disposition to meningo-gastric fevers. The same influences, continued during the whole year in hot countries, must necessarily increase, with the activity of the biliary system, its power over the other parts of the economy; and thus establish a predominance of the bilious constitution through both health and disease.

As for the sanguine temperament, so generally met with among northern nations, it is the necessary consequence of the continual and very energetic re-action of the powers of circulation, against the effects of external cold. It is only by the constant activity of the heart and vessels that calorification can be effected with the necessary vigour. Now, the effects of this redoubled action are the same to the organs of circulation as to the muscles under the influence of volition; in both, exertion increases the power of the organs exerted. The diseases of the nations of the north, analogous to their temperament, have, for the most part, their seat in the system of sanguineous vessels: their character is eminently inflammatory.

Lastly, the lymphatic state of nations living under a moist climate is nothing more surprising than the aqueous nature of plants, and small density

* It is thus that, in the arts of imitation, the ideal grows up—now from the exaggeration of features, now from the union of qualities which nature has produced separate.

of the wood in trees growing under the influence of a foggy air. Animal bodies, like plants, absorb by their surfaces, and become gorged with humours, the excess of which always produces a remarkable slackening of activity in the organic motions.

The temperament of which the character is the predominance of one organ or system of organs, departs from that ideal state where all the powers are reciprocally balanced, so as to exhibit in the living economy a perfect equilibrium. This latter state, which has, perhaps, never been found but in the imaginations of physiologists, and which was called by the ancients the temperate temperament, (*temperamentum temperatum*) being taken as the type of health, it follows that this temperament is already a step made towards disease. Yet the action of the predominant system is not in such excess as to destroy all equilibrium, and impede the action of life: but let the constitutional dispositions be much increased, the disease is begun; and this transition takes place in the conversion of the lymphatic temperament into scrofula.* In the scrofulous constitution there is at once activity of the absorbing mouths, great facility of absorption, inertness of the vessels and lymphatic glands, weakness of the absorbents, and consequently a thickening and stagnation of the liquids absorbed. The same thing is seen in the lymphatic temperament, characterised by the activity of the inhaling mouths, and the debility of the lymphatic system, as Professor Cabanis was aware,† when he refuted the opinion of those who ascribe the lymphatic temperament to the excess of activity in the absorbent system, though the only part of this system really quickened is that which immediately performs absorption, whilst the rest is in a state of perfect atony.

CCXXXVII. *Varieties of the human species.*—The power of producing, by copulation, individuals which are alike, is considered by naturalists as the most certain test for fixing the species in red and warm-blood animals. This power of self-perpetuation, by a constant succession of similar beings, is found in all the races composing the human species, however different in colour, structure, and manner of life. Men, then, are but one species; and the difference that appears in them, according to the region of the globe they inhabit, can only constitute varieties or races. I admit, with M. Lacépède, the worthy continuator of Buffon, four principal races of the human species, which I shall call, like him, the *European Arab*, the *Mongul*, the *Negro*, and the *Hyperborean*. We might add a fifth, the American, were it not most probable that the new continent is peopled by inhabitants, who, coming from the old, either by land in the austral hemisphere, or along the immense archipelago of the Pacific Ocean, have been altered by the influence of that climate, and the yet virgin soil, so that they are to be regarded less as a distinct race than a simple variety.‡

There is, in truth, this difference between varieties and races,—that in these lasts there are implied modifications more profound, more essential differences, changes not confined to the surface, but extending to the very structure of the body; whereas to make a variety, nothing more is needed than the superficial influence of climate on the integuments, which it colours, and on the hairs, which it makes longer or shorter, lank or curled, hard or soft. An Abyssinian, scorched by the heat of an almost tropical sky, is as black as the negro under the equator; yet they are by no means of one race, since

* See *Nosographie Chirurgicale*, tome i. for the history of scrofulous ulcers, from which this paragraph is taken entire. The author in that work has aimed at introducing physiology into surgery, till then exclusively abandoned to explanations of the grossest mechanism.

† Of the Relations of the Physical and Moral Man, by G. Cabanis, Senator, Professor in the School of Medicine in Paris, &c.

‡ See Appendix, Notes P P.

the Abyssinian, a negro only in colour, resembles the European in the cast of his face, and the proportions of all his parts.

The characteristics of the *European Arab race*, which takes in the inhabitants, not of Europe only, but of Egypt also, Arabia, Syria, Barbary, and Ethiopia, are an oval or almost oval face, in the vertical direction, a long nose, a prominent skull, long and commonly lank hair, a skin more or less white. These fundamental characteristics are no where more decided than in the north of Europe. The inhabitants of Sweden, Finland, and Poland, give the prototype of the race: their stature is tall, their skin of perfect whiteness, their hair long, lank, and of a light colour ; the iris generally bluish. The Russians, the English, the Danes, the Germans, are already removed somewhat from this primordial type : the colour of their skin is of less pure white, their hair of a deeper hue. The French seem to stand midway betwixt the nations of the north and those of the south of Europe. Their skin is shaded with a deeper dye, their hair less straight, and more of a chestnut and brown colour. The Spaniards, the Italians, the Greeks, the European Turks, and the Portuguese, are browner, their hair in general black. Lastly, the Arabs, the Moors, and the Abyssinians, have hair in some measure black and crisp, the skin tawny ; and might serve for the step from the European Arab to the Negro race, which is, however, distinguished from them by the flatness of the forehead, the smallness of the skull, the slope of the line measuring the height of the face, the thickness of the lips, the projection of the malar bones : and further, by a darker skin, thicker, greasy, and, as it were, oily,—as well as by shorter, finer, curly, and woolly hair.

The *Mongol race* has the forehead flat, the skull jutting but little, the eyes looking rather obliquely outwards ; the cheeks are prominent, and the oval of the face, instead of extending from the forehead to the chin, is drawn between the two malar bones. The Chinese, the Tartars, the inhabitants of the Peninsula, of the Ganges, and of the other countries of India, of Tonquin, Cochin-china, Japan, of the kingdom of Siam, &c. compose this race, which is more numerous than all the others, apparently more ancient, and which is spread over a greater extent of surface than the European Arab race, and yet greater than the Negro race, since it reaches from the fortieth to the sixtieth parallel of latitude, occupying an arc of the meridian of nearly 75° ; whilst that which measures the countries of the European race is only of 50°, and the Negro race lying under the equator, between the tropics of Cancer and of Capricorn, is bounded within the limits of an arc of from 30° to 35°.*

The *Hyperborean race*, situated in the north of the two continents, in the neighbourhood of the polar circles, composed of the Laplanders, the Ostiaks, the Samoiedes, and the Greenlanders, is characterised by a flat face, a squat body, and a very short stature. This degraded portion of the human species evidently derives from the climate its distinctive characteristics. Striving for ever with the inclemency of a severe climate, and the destructive action of an icy temperature, Nature, fettered in her motions, and shrunk in her dimensions, can produce only beings whose physical imperfections explain their almost barbarous condition.

The small progress of the *Negroes* in the study of the sciences and in civilisation ; their decided taste and singular aptitude for all the arts which require more taste and dexterity than understanding and reflection, as dancing, music, fencing, &c. ; the figure of the head, which is midway between that of the European and the ourang-outang ;† the existence of the intermaxilla-

* Lacépède, *Géographie Zoologique.*

† The black colour of the skin in Negroes seems owing, as I have already said, to the scorching of the gelatine, which is the base of

ry bones at an age when with us the traces of their separation are completely effaced; the high situation and small developement of the calf of the leg;—have been arguments more specious than solid to those who have endeavoured to abase this portion of the human species, in order to justify an iniquitous traffic and a cruel tyranny—reproaches of civilised men, which they must wipe off by other means than a presumptuous assertion of their own dignity, or a proud insult on the native character of those whom they themselves have cast into degradation.

Without admitting this belief, which owes its origin to a thirst for riches, we cannot help acknowledging that the differences of organisation draw after them a striking inequality in the developement of the moral and intellectual faculties. This truth would appear in its full light, if, after summarily indicating, as I have just done, the physical characteristics of the races of men, I could unfold their moral differences as real, and not less marked, by opposing the activity, the versatility, the restlessness, of the European, to the indolence, the phlegm, the patience of the Asiatic; examining what is the power or the character of nations, the fertility of soil, serenity of sky, mildness of climate; shewing by what catenation of physical and moral causes the empire of custom is so powerful over the people of the East that we find in India and China the same laws, manners, and religion, which prevailed there long before our era; inquiring by what singularity, well worthy the meditation of philosophers and politicians, these laws, this worship, and these manners, have undergone no change amidst the revolutions which have so often taken place among those nations, many times conquered by the warlike Tartars; shewing how, by the irresistible ascendancy of wisdom and knowledge, ignorant and ferocious conquerors have adopted the usages of the nations they have subjugated; and proving that the stationary condition of the sciences and arts among those who, so long before ourselves, were in possession of the advantages of civilised society, is derived not so much from the imperfection of their organisation, as from the degrading yoke of a religion loaded with absurd practices, and which makes knowledge the exclusive birthright of a privileged cast.* But such an undertaking, besides exceeding the limits I have prescribed myself, does not belong directly to my subject.

The *Albinoes* of Africa, the *Cagots* of the Pyrenees, and the *Cretins* of the Valais, cannot be given as varieties of the human species. They are infirm, feeble, degraded beings, incapable of reproducing an existence which has fallen to them in the midst of a healthy, vigorous, and robust population.

We are not to believe what some travellers have written on the existence of tribes of giants that have appeared on the Magellanic coast. The Patagonians, concerning whose stature there is so little agreement in relations, are

the rete mucosum of Malpighi. This colour, acquired in a long succession of ages, perpetuated and transmitted by generation, is become one of the characteristic features of the Negro race. M. Volney, in a work which should be a model to all travellers, grounds on the face of the blacks a conjecture as ingenious as it is probable. He observes, that it exhibits precisely that state of contraction which our face takes when it is struck by light, and a strong reverberation of heat; then, says this philosophical traveller, the cheek-bones rise, the brow and the eye-lids contract, and the lips project. Must not this contraction of the movable part have influenced, in course of time, the hard parts, and even moulded the structure of the bones?—*Voyage en Syrie et en Egypte*, tom. i. p. 70, sixième édition.

* We must assign further, as a main cause of the want of progress of the Indians and Chinese in the arts and sciences sprung from civilisation, the imperfection of their alphabet, which, being composed of a multitude of characters, does not, like ours, represent sounds, but ideas. It belongs not to our subject to shew how much signs so defective must confine the sphere, and fetter the combinations, of the mind.

See, concerning the religion of the Brahmins and the Indian customs, Raynal's Philosophical History; the Asiatic Researches; Institutes of Menu, Edin. Review, xxxii.; Ward's View of the History of the Hindoos; Halked's Code of Gentoo Laws; Colebrooke's Digest of Hindoo Law.

men very well formed, and whose height does not exceed ours more than nine or ten inches. The Laplanders, whose stature is the smallest, are as much below as the Patagonians are above; it does not exceed from four feet to four and a half. In the midst of ourselves, individuals reach, from time to time, a stature sufficient to entitle them to the name of giants; whilst others, shrunk in all their proportions, are a renewal of the pigmies. Such was Bébé, the dwarf of Stanislaus, king of Poland; Goliah, spoken of in the book of Kings, (ch. xvii. v. 4.); the king Og, (Deut. ch. iii. v. 2); and many others, whose stature varies from six to ten feet high.

CCXXXVIII. *Of old age and decrepitude.*—The human body, which, from the twentieth year of life, ceases to grow in height, increases in every dimension during the twenty succeeding years. After this period, far from growing, it begins to decay, and loses daily a part of its strength. The decay proceeds at the same rate as the growth, and is not more rapid; since man requires from thirty to forty years in reaching to his full growth, and takes about the same time in his progress to the grave, provided no accident hurries him to an untimely end.* The whole bulk of the body diminishes,† the cellular tissue becomes collapsed, and the skin wrinkled, especially that of the forehead and face. The hairs of the head and over the rest of the body turn gray, then white; the organic action becomes languid; the fluids become more disposed to putrefaction (Hunter); hence, at this period of life, all diseases of debility are more frequent, and attended with greater danger.

Decay succeeds old age. The sensibility of the organs is blunted; the physical and intellectual faculties undergo a gradual decay; man ceases to be impressed in the same manner by surrounding bodies. His judgments are incorrect, because self-love preventing him from being aware of the changes which he has undergone, he is more disposed to ascribe to an universal degeneracy the difference which exists between the sensations which he now experiences and those which he experienced in his youth, (*laudator temporis acti*). The digestion is bad, the pulse weak and slow; the absorption difficult, from the almost complete obliteration of the lymphatics and the induration of the conglobate glands, the languid secretion, and imperfect nutrition. The old man is slow in all his actions and stiff in all his motions; his hair falls off, his teeth drop from their sockets; the cartilages ossify, the bones grow irregularly and become anchylosed, their internal cavity enlarges; all the organs waste; and the muscular fibres are indurated and rigid. The bones become heavier, from the gradual accumulation of phosphate of lime; and if, on the contrary, those of the skull, as is justly observed by Sœmmer-

* The duration of life may be estimated by that of the growth. A dog ceases to grow at the end of two or three years, and lives only ten or twelve; man, whose growth requires a space of from twenty to thirty years, attains to the age of ninety or a hundred. Fishes live several centuries, their developement requiring a considerable number of years.

† The diminution of the entire bulk of the body of aged persons frequently gives place to an augmentation of size, especially of the trunk of the body. This is entirely owing to the increased deposit of fat, which often supervenes at this age, and which appears to depend on the energy of the system being insufficient to the complete assimilation of the nutritive materials, and on the slow circulation of the blood in the capillary vessels, which state of the circulation seems to give rise to the predominance of hydrogen and carbon in the blood which these vessels and the veins contain. The abundance of these elements in the extreme vessels being the source whence the fat is so largely formed, the combination of them into that particular substance is the result of the same state of the vital energies which favours their predominance. This increase of bulk, owing to the augmentation of the secretion of fat, in persons advanced in life, is far from being favourable to the free exercise of the various functions; for certain organs being incommoded with the weight and bulk which they thus acquire, are still farther embarrassed in their organic movements, the circulation in the extreme vessels is rendered still slower, and thus the cause of the increased secretion of fat goes on increasing. This sufficiently accounts for the fact, that, in general, leanness is at an advanced age more favourable to long life than the opposite state.

ing, become lighter, it is that they are in a manner worn out by the continued motions of the brain on their internal surface.

The ossification of some of the cartilages,—for example, of those of the ribs and vertebræ,—is productive of remarkable effects. The ribs becoming soldered in a manner to the sternum, perform very imperfectly their natural motions, (LXXI.) which contribute to the enlargement of the chest. This cavity dilating less fully, the pulmonary combinations, which are the abundant sources of animal heat, take place in a less effectual manner; and this, joined to a want of tone and energy in the lungs and in all the organs, lowers the temperature of old people, as was observed by the father of physic;* a circumstance, however, which has been denied by De Haen.

Those fibro-cartilaginous laminæ, with oblique fibres crossing each other, which unite so firmly the bodies of the vertebræ, become indurated, dried, and shrivelled, sink under the weight of the body, and do not recover their former thickness, so that the stature is really reduced; besides, the weakened condition of the muscles which raise the trunk makes the weight of the viscera bend forward the vertebral column, whose different parts may remain fixed in this attitude, so that the whole column, consisting of twenty-four vertebræ, may come to consist of only seven or eight distinct bones. It should not be imagined, however, that all the soft parts become more compact, for several, as Haller observes, (the muscles, for instance), become softer,† and seem, in losing a part of their vital properties, to draw towards a speedy dissolution; not that death is entirely owing to the accumulation of phosphate of lime, which enters into the composition of all the organs, converts into ossific matter the whole osseous system, and interrupts the action of the animal machine. If this ossific matter invade every part of the animal system, it is because the digestive powers, gradually weakened, cease to affect in a suitable manner the alimentary substances. The exuberance of calcareous salts is, therefore, not so much the cause as the effect of the successive destruction of the vital powers.

The slowness, the rigidity, and the difficulty of moving, do not depend so much as is thought on the induration of the ligaments and other fibrous organs: these ligaments become softened and relaxed to a considerable degree, so that luxation is more easily performed after death in old people. In them, likewise, organs which in youth have a degree of consistency, become flaccid and soft: this is the case with the heart, which is found collapsed in old people, its cavities remaining entire, while in young persons and in adults their parietes are firm and not in close contact.

The brain becomes harder and firmer, and less soluble in alkalies; its albumen appears more completely oxidised than in younger subjects; impressions are less easily made, and the motions necessary to the operations of the understanding are performed with difficulty. Hence, in decrepitude man returns, as far as relates to his intellectual faculties, to a state of second childhood, limited to certain recollections, which are at first confused, and in the end completely lost: incapable of judgment or will, or of new impressions, sleep resumes its influence; reduced to a mere vegetative existence, he sleeps the greatest part of the day, and wakens only to satisfy his physical wants and to take food, which he digests very imperfectly; for, in the first place, the want of teeth prevents his being able to divide sufficiently the different substances; and, in the next place, the supply of saliva, of gastric

* "Senibus autem modicus est calor * * * * frigidum est enim ipsorum corpus."—HIPPOCR. *Aph.* xiv. sect. 2.

† "Non ergò in sola rigiditate causam senii mortis oportet ponere; nam ex defectu irritabilitatis, plurimi in senibus musculi languent, mollesque pendent."—*Elementa Physiol.* tom. viii. 4to. lib. 30.

and intestinal juices, is almost interrupted; the bile and other fluids are less active, and the intestinal tube is without energy. Universal rigidity will be admitted as one of the principal causes of death, if it be considered that women, in whom the organs are naturally softer, are longer in reaching that state, are more retentive of life than men, and generally live to a greater age.

The body, therefore, dies slowly and by degrees, says the eloquent M. de Buffon; life gradually becomes extinguished, and death is but the last term of this series of degrees, *the last shade of life.*

CCXXXIX. *Of death.*—Long, in fact, before the close of life, man loses the power of reproduction; and in the course of the agony which serves as a passage between life and death, the organs of sense first become insensible to all sorts of impressions; the eyes grow dim, the cornea fades, the eye-lids close, the voice becomes extinct, the limbs and the trunk motionless; yet the circulation and respiration continue to be carried on, but at last cease, first in the vessels furthest from the heart, and then gradually in the vessels nearest that organ. Respiration, gradually slackened, being entirely suspended after a strong expiration,* the lungs no longer transmit the blood which the veins bring from every quarter to the heart. This fluid stagnates in the right cavities of the heart, and these die last, (*ultimum moriens*); and distended by the blood which collects within them, they attain a capacity exceeding greatly that of the left cavities, which are, to a certain degree, emptied.

Such is the course of natural death: the brain ceases to receive from the weakened heart a sufficient quantity of blood to keep up sensibility; there remains still some degree of contractility in the respiratory muscles; it is soon exhausted, however, and the circulatory motion of the blood ceases with the life of all the organs, of which this fluid is one of the principal movers.

As to accidental death, it is always determined by the cessation of the action of the heart and brain; for the death of the lungs occasions that of the whole body only by preventing the action of the heart, by interrupting its influence on the encephalic organ. In natural death, therefore, life becomes extinguished from the circumference to the centre; in accidental death, on the contrary, the centre is affected before the extremities.

Bichât, in his work entitled, "*Recherches sur la Vie et la Mort,*" has given a very complete account of the manner in which the organs of the animal economy cease to act *in articulo mortis;* but, like all the authors who went before him, he has limited his inquiries to certain functions. No one has attempted to extend them to the phenomena of the action of the brain, nor has any one traced the order in which the various faculties of thought and of sensation vanish. I shall endeavour faithfully to mention the results of several hundred observations of my own on this subject.

The close of life is marked by phenomena similar to those with which it began. The circulation first manifested itself, and ceases last. The right auricle is the part first seen to pulsate in the embryo, and in death is the last to retain its motion. The phenomena of nutrition, to which the fœtal existence is almost entirely limited, continue even when the organs destined to establish a relation with the beings that surround us have long been sunk into a slumber from which they are never to be roused.

The following is the order in which the intellectual faculties cease and are decomposed.† Reason, the exclusive attribute of man, first forsakes him.

* Does this last and powerful expiration, often attended by sighing, depend on the spasmodic contraction of the muscles of expiration; or rather does it not depend on the re-action of the elastic parts which form the chest—a re-action which suddenly ceases to be counterbalanced by the vital properties?

† I need not inform the reader that I am not

He begins by losing the faculty of associating judgments, and then of comparing, of bringing together, and of connecting, a number of ideas, so as to judge of their relations. The patient is then said to have lost his consciousness, or to be delirious. This delirium has generally for its subject the ideas that are most familiar to the patient, and his prevailing passion is easily recognised. The miser talks in the most indiscreet manner of his hidden treasures, the unbeliever dies haunted by religious apprehensions. Sweet recollections of a distant native land, then it is that ye return with your all-powerful energy and delight!

After reasoning and judgment, the faculty of associating ideas is next completely destroyed. The same occurs in fainting, as I once experienced in myself. I was conversing with one of my friends, when I felt an insuperable difficulty in associating two ideas, from the comparison of which I wished to form a judgment. Yet syncope was not complete; I still preserved memory and the faculty of feeling. I could distinctly hear those about me say, "he is fainting," and exert themselves to relieve me from this condition, which was not without enjoyment.

The memory then fails. The patient who, during the early part of his delirium, recognised the persons about him, no longer knows his nearest and most intimate friends.

At last he ceases to feel, but his senses vanish in succession and in a determinate order: the taste and smell cease to give any sign of existence; the eyes become obscured by a dark and gloomy cloud; the ear is yet sensible to sound and noise; and no doubt it was on this account that the ancients, to ascertain that death had really taken place, were in the habit of calling loudly to the deceased.

A dying man, though no longer capable of smelling, tasting, hearing, and seeing, still retains the sense of touch: he tosses about in his bed, moves his arms in various directions, and is perpetually changing his posture; he performs, as was already said, motions similar to those of the fœtus within the mother's womb.

CCXL. *Of the period of death.*—This period is nearly the same with all men: whether they live near the poles or under the equator, whether they live exclusively on animal or vegetable substances, whether they lead an active life, or consume their existence in disgraceful sloth,—few live beyond a hundred years. There are, however, cases of men who have lived far beyond that period, as, for example, those mentioned in the Philosophical Transactions, one of whom lived to a hundred and sixty-five.

Few men, however, attain a hundred years, and death, even when natural, overtakes us from the age of seventy-five to a hundred.

Difference of climate, though producing little difference in the duration of life, has, however, a remarkable influence on rapidity of growth. Puberty, manhood, and old age, come on much sooner in warm climates than in northern countries; but this premature developement, which shortens the duration of the periods of life, augments in the same proportion that of old age.

It is, however, difficult to say at what precise period old age begins. Is it towards the fortieth year, when the body begins to decrease and to decay? Can the change of the colour of the hair be considered as the certain sign of old age? We daily see young men with gray hair. May we determine

here speaking of the immortal soul, of that divine emanation which outlives matter, and which, freed from our perishable part, returns to the Almighty. I am speaking merely of the intellectual faculties common to man, and to those animals which, like him, are provided with a brain.

its accession by the cessation of the functions of generation and the incapacity of reproduction? Fecundity, whose term is so easily determined in woman by the cessation of the menses, is in man very equivocal; the emission of the seminal fluid is an uncertain sign, from the difficulty of distinguishing the mucus of the vesiculæ seminales and of the prostate from the truly prolific semen. Erection is likewise a sign not to be relied upon: this state may be occasioned by sympathetic irritation, by the compression of the bladder distended with urine on the vesiculæ seminales. It is more difficult than is imagined to determine from observation the period at which, in the human species, the male is entirely deprived of the power of generation; and it may be said that, in establishing the period of from forty-five to fifty-five as the beginning of old age in our climate, there will be found men arrived at that state before having reached that age; as, on the other hand, others will be found after the age of fifty-five with all the characters of manhood. The climacterical period of sixty-three is the decided and confirmed period of old age. Whatever regimen may have been followed, man at that age is truly old, and cannot but be aware of it.

CCXLI. *Of the probabilities of human life.*—Man dies at all ages; and if the duration of his life surpass that of the lower animals, the great number of diseases to which he is liable renders it much more uncertain, and is the cause why a much smaller number arrive at the natural term of existence. It has been attempted to discover what are the probabilities of life, that is, to ascertain from observation how long a man may expect to live who has already reached a determinate age. From late accurate observations of the age at which a number of persons have died, and from a comparison of the deaths with the births, it has been ascertained, that about one-fourth of the children that are born die within the first eleven months of life; one-third under twenty-three months; and one-half before they reach the eighth year. Two-thirds of mankind die before the thirty-ninth year, and three-fourths before the fifty-first; so that, as Buffon observes, of nine children that are born, only one arrives at the age of seventy-three; of thirty, only one lives to the age of eighty; while out of two hundred and ninety-one, one only lives to the age of ninety; and, in the last place, out of eleven thousand nine hundred and ninety-six, only one drags on a languid existence to the age of a hundred years.

The mean term of life is, according to the same author, eight years in a new-born child. As the child grows older his existence becomes more secure, and after the first year he may reasonably be expected to live to the age of thirty-three. Life becomes gradually firmer up to the age of seven, when the child, after going through the dangers of dentition, will probably live forty-two years and three months. After this period, the sum of probabilities, which had gradually increased, undergoes a progressive decrease; so that a child of fourteen cannot expect to live beyond thirty-seven years and five months; a man of thirty, twenty-eight years more; and, in the last place, a man of eighty-four, one year only. From the eighty-fifth to the ninetieth year, probabilities remain stationary, but after this period, existence is most precarious, and is painfully carried on to the end. Such is the result of observation, and of calculations on the different degrees of probability of human life, by Halley, Graunt, Kersboom, Wargentin, Simson, Déparcieux, Dupré de St. Maur, Buffon, d'Alembert, Barthez, and M. Mourgues, who has just published his observations, collected at Montpelier in the course of a great number of years, and with the most scrupulous accuracy.*

* From the observations made during more recent periods, it would appear that the mean duration of human life has experienced an increase of nearly five years in the greater num-

I should enter more fully into this subject, but that it belongs rather to the department of political economy than to that of physiology.

Do the calculations on the probabilities of human life present results applicable to the generality of cases, and is the mean duration of existence nearly the same with all men, in all countries and climates? The shepherd of the Pyrenees, who lives happy in the innocence of a pastoral life, breathing the pure air of his mountains,—is he, in this respect, subject to the same laws as the inhabitant of populous cities, exposed to the inconveniences attending numerous collections of men; inconveniences which, viewed in a philosophical point of view, or which, being greatly over-rated, have so often furnished a text to the meditations of philosophy, and to the idle declamations of oratory?*

Does life experience a progressive diminution in proportion to the duration of the world; and to say nothing of the time preceding the flood, when, according to the Book of Genesis, men lived several hundred years, did the men of former times live longer than those of our own? This is very im-

ber of European countries. This may be in some measure owing to the introduction of vaccination, but perhaps the chief causes may be found in the progress of science and civilisation, giving rise to a general improvement in the habits of life, particularly with regard to ventilation and cleanliness; to better habitations; a more ample supply of food, clothing, and fuel; greater sobriety; a more general cultivation of the soil, and consequent removal of the sources of several diseases; to improved management of children; and to the advanced state of medical knowledge.

The same causes that conduce to longevity must of course increase the population of a country. The suppression of monastic celibacy, and the more equal distribution of landed property, consequent on the revolution in France, have tended to increase the population of that country, notwithstanding the destructive wars in which she has been engaged.—*J. C.*

* In order to answer these questions in a satisfactory manner, it would be necessary to have tables of mortality kept with care in the different countries and climates of the globe. The religions and superstitions of the East, of all Africa, and of a great part of America, oppose invincible obstacles to these researches, independently of those resulting from the state of civilisation, and the policy of the various governments of these countries. Judging, however, from the results already before us, the northern kingdoms of Europe appear to be those in which mankind enjoy the longest term of existence. The tables of mortality of the empire of Russia for the year 1811, gave, in 828,561 individuals deceased belonging to the Greek church, 947 who had reached a hundred years and upwards; amongst whom were 83 of 115 years of age, 51 of 120, 21 of 125, 7 of 130, 1 of 135, and another who had reached 140.

According to the abstract of the population returns of Great Britain in 1821, the number of individuals in England, aged from 90 to 100 years, was 9·90 in every 20,000; and of those aged 100 and upwards, 34: the general mortality was 1 in 57. In Scotland, those aged from 90 to 100 was 14·13; and 100 and upwards, 1·903 in every 20,000. In Wales, the number of persons aged from 90 to 100 was 17·97; and of those aged 100 and upwards, ·50 in 20,000: the mortality was 1 in 69.

The maximum longevity was found to be in Scotland, in the shire of Ross and Cromarty. Here the proportion of individuals aged from 90 to 100 was 34·39 to the 20,000; and of those aged 100 and upwards, 9·22. In the shires of Inverness and Argyle, the proportion of persons aged from 90 to 100 were 31·49 and 29·84, respectively, to 20,000. In 1811, the population of Scotland was 1,865,900; in 1821 it was 2,135,300.

The first actual enumeration of the inhabitants of England and Wales was made in 1801, and gave a population of 9,168,000, and a mortality of 1 in 44·8. The second was made in 1811, and gave a population of 10,502,900, and a mortality of 1 in 50. The third and last, which took place in 1821, has given an enumeration of 12,218,500, and a mortality of 1 in 58.

It appears from these returns, that the healthiest counties in England and Wales are Pembroke, Sussex, Cornwall, Cardigan, and Monmouth, the mortality in these being 1 in about 71; and that the least salubrious are Middlesex, Kent, Surry, and Warwick, the mortality being in these 1 in about 50. It is not easy to explain altogether the difference in salubrity in the different counties. Locality is, doubtless, an important agent. Cities and large manufacturing towns modify greatly the ratio of mortality in a particular district. This is well illustrated with respect to London. In 1700, the annual mortality of this city was 1 in 25; in 1750, 1 in 21; in 1821 and the four preceding years, 1 in 35; in 1810, 1 in 38; and in 1821, 1 in 40.

It must be evident, that the increase or diminution of the population of a district, as well as the mean term of life in it, must depend upon the nature of the climate and soil, its mean elevation and temperature, the state of its civilisation and cultivation, pursuits of its inhabitants, and means of subsistence. The government and religion of a country also exert no inconsiderable control on the mean duration of human life, and increase of its population. Together with these already mentioned, many other causes of a moral and physical nature may be adduced, as influencing in no slight degree the extent of population, and the salubrity of a district or country.—*J. C.*

probable: among the Egyptians, the Hebrews, the Greeks, and Romans, there were very few instances of persons living to the age of a hundred years, and instances of longevity are perhaps more frequent among the moderns.

The art of providing for the wants of life making daily progress, it is very probable, that far from being shortened, the term of human life may be lengthened a certain number of years beyond its ordinary duration. This idea is, it is true, contrary to the commonly received opinion of the progressive depravity of mankind in all ages; but the golden age never existed but in the imagination of poets, and the daily complaints of morose old age have their origin in motives easily understood by the physiologist. He whose sentiment is blunted by a long course of years, is affected in a very different manner by surrounding objects. As to the old man, flowers have lost their scent and beauty, fruits no longer retain their flavour; the whole of nature seems dull and colourless. But the cause of all these changes is within himself; every thing else remains as it was. Always equally fruitful, Nature exposes every thing to the action of her inexhaustible crucible, maintains every thing in a state of everlasting youth, and preserves a freshness ever renewed. Individuals die, species are renovated; life every where arises in the midst of death. The materials of organised bodies enter into new combinations, and serve in forming new beings, when life ceasing to animate those to which they belonged, putrefaction seizes upon them and effects their destruction.

CCXLII. *Of putrefaction.*—Here the history of life ought to terminate: if, however, it be considered that the changes which bodies experience after death throw a considerable light on its means, its ends, and its nature, there will be an obvious necessity for shortly inquiring into the different phenomena which accompany the decomposition of animal substances. And this investigation appears to me to belong to the department of physiology, until the aspect of the body ceases to recall the idea of its former state, and until the last lineaments of organisation are completely effaced. As soon as life forsakes our organs, they become subject to the laws of physics operating on substances that are not organised. An inward motion takes place within their substance, and their molecules have the greater tendency to become separated from one another as their composition is more advanced. Chemistry informs us, that the tendency to decomposition of bodies is in direct ratio to the number of their elements; and that a dead animal body is capable of remaining unchanged, in proportion as its composition is more simple, and its constituent principles less numerous and less volatile.

Before putrefaction can come on in the human body, it must be entirely deprived of life, for the vital influence is most powerfully antiseptic; and one might say that life is a continual struggle against the laws of physics and chemistry. This vital resistance, alluded to by the ancients when they said that the laws of the microcosm were in perpetual opposition to those of the universal world, and that these in the end prevailed—this power which is in a state of perpetual re-action, manifests itself in life: the latter, considering only the results, might therefore be defined as follows—*the resistance opposed by organic bodies to the causes incessantly tending to their destruction.* By attending to all these phenomena, it will be seen that all of them tend to one end—the preservation of the body, and that they obtain it by keeping up a perpetual struggle with the laws which govern inorganic substances.

It might appear singular that death should furnish a just idea of life, did we not know that it is by comparing that we are enabled to distinguish, to judge, and to arrive at knowledge.

Putrefaction takes place and is completed only in substances deprived of life. A mortified limb loses its vitality before putrefaction comes on; and if Nature preserve sufficient energy to resist this destructive process, she draws,

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by a line of inflammation, the separation between the dead and the living part. Life and putrefaction are, therefore, two absolutely contradictory ideas; and when, in some diseases, there is observed a tendency in the solids and fluids to spontaneous decomposition, this tendency to putrefaction should not be mistaken for putrefaction itself.

Several conditions are required to enable putrefaction to affect the human body after death. In the first place, a mild temperature, that is, above ten degrees of Reaumur's thermometer; in the next place, a certain degree of moisture; and lastly, the presence of air. This last condition, however, is not so necessary as the two former, since substances undergo putrefaction in a vacuum, though more slowly. The air consequently promotes a decomposition only by carrying off the element, which rises in vapours. On the other hand, an icy cold, or a degree of heat approaching to boiling, prevents it; the former by condensing the parts; the second by depriving them of moisture, the complete absence of which accounts for the preservation of the Egyptian mummies.

The phenomena of putrefaction, resulting from a series of peculiar attractions, are modified in various ways according to the nature of the animal substances which are subjected to it, to the media in which it takes place, to the different degrees of moisture and temperature, and even according to its different periods. Notwithstanding these innumerable varieties, one may say, that all exhale a certain cadaverous smell, are softened, increase in bulk, acquire heat, change colour, assume a greenish, then a livid and dark-brown colour: there are, at the same time, disengaged a great number of gaseous substances, of which ammonia is the most remarkable, either from its quantity, or from being given out by animal substances from the moment when decomposition begins to the period of the most complete dissolution. This gas produces the pungent and putrid smell which exhales from dead bodies.

Towards the termination of putrefaction, there is disengaged carbonic acid gas, which, combining with ammonia, forms a fixed and crystallisable salt. Besides these products, there are given out sulphuretted and phosphoretted hydrogen, azote, carbonic acid, and all the gaseous matters that may be produced by their respective combinations. In the last place, animal substances, when reduced to a residue containing oils and salts of different kinds, form a mould, from which plants draw the principles of a luxuriant and vigorous vegetation. The bones, those least alterable parts of the organised machine, in time become dried by the slow combustion of their fibrous part, and by the evaporation of their medullary juices. At last, reduced to an earthy skeleton, they crumble into dust, and this dust is dissipated on opening the tombs in which they were laid.

Thus, in course of time, is effaced all that could recall the idea of our physical existence.

Putrefaction, considered in a philosophical point of view, is but a means employed by nature to restore our organs, deprived of life, to a more simple composition, in order that their elements may be applied to new creations (*circulus æterni motûs**). Nothing, therefore, is better proved, than the metempsychosis of matter;† which warrants the belief that this religious dogma, like most of the fabulous worships and imaginations of antiquity, is but a veil ingeniously thrown by philosophy between nature and the ignorant.

* BECCHER, *Physica subterranea*.

† Matter is eternal in this sense, that the molecules of bodies merely pass from the one into the other; they survive the destruction, or rather the dissolution, of organic and inorganic beings, when the former, ceasing to live, restore to the inexhaustible fund of Nature those elements which she lends without ever parting with them.

Mancupio nulli datur, omnibus usu.—LUCRET lib. iii.

APPENDIX:

BY

JAMES COPLAND, M.D. &c.

ADDITIONAL NOTES

TO THE

PRELIMIMARY DISCOURSE.

OF LIFE.

(NOTE A. See pp. 1, 8, 31, 139.)

PHYSIOLOGISTS are divided into those admitting a principle of life, and those attributing the vital phenomena to organisation solely—the latter class contending that life presupposes organisation, the former that organisation presupposes the presence of life. An attentive consideration of the phenomena presented by the whole range of organised bodies, and a fair contrast instituted between these and the changes which inanimate matter exhibits, will readily convince the mind unbiassed by preconceived notions which of the two doctrines to prefer.

Those who contend that life is the result of organisation ought to explain in what manner the organisation itself took place; they should shew the means employed to produce the disposition of parts, which they conceive requisite to give rise to vital phenomena. If they deny the primary influence of a vital power associated with the particles of matter, let them explain by what other agency the different atoms can assume organic actions. All effects must have a cause, and it is better to assign one according to which difficulties may be accounted for, than to contend for the efficiency of properties or powers of the existence of which we have no evidence, and which, even granting them to exist, can only be considered as inferior agents, or peculiar manifestations of a vital principle.

With respect to this class of physiologists, it may be remarked generally;—1st. That explanations of organisation which admit not of the primary and controlling influence of vitality, however applicable they may seem to those who look only at the gross relations of things, cannot satisfactorily account for the origin and nature of the phenomena to which they relate; for, however terms may be substituted, or illustrations multiplied, the changes which continually take place in living bodies cannot be explained by means of the laws and affinities which characterise the combinations of inorganised matter.

2d. In order to explain the phenomena which are more justly ascribed to a vital principle, the supporters of the doctrine of organism have recourse to the substitution of properties, occult qualities, impulses, and motions; and when required to shew wherein these qualities, impulses, and properties, are different from those which we observe in organised matter, and are there subjected to our experience, they endeavour to get rid of the difficulty by denominating them vital; thus tacitly admitting the very principle, in the place of which such insufficient properties are attempted to be substituted; and, after all, without the smallest success in preventing a recurrence to this principle, of which all these properties, admitting their existence, are nothing else than the results: for, however we may denominate them, we merely substitute expressions which (if they convey any meaning) imply only the existence of certain effects or operations which are inferior agents or instruments, under the control of vitality, in the production of the organic phenomena.

From this view, therefore, of the subject, it appears that the argument used against the existence of a vital principle is rather verbal than real. The organists cannot even prove the basis of their doctrine, for they cannot shew that organisation came into existence before the effects which they impute to it; and while they bestow properties and qualities on organised matter similar to those imputed to a vital principle, and different from those which characterise inorganised matter, although they cannot point out the difference otherwise than by calling them vital, they virtually admit the existence of the principle against which they contend: for what principle in nature, we would ask, can be shewn to exist, or how can its existence be rationally inferred, but by certain properties and qualities which are peculiar to itself, and which, moreover, as respects this principle, are dissimilar and greatly superior to, and indeed hold a controlling influence over, all the other properties of matter with which we are acquainted?

Such, therefore, being the case, we are justified in recurring to the belief in a vital principle, which, allied to matter, controls its changes and forms, and to which principle the laws and affinities of matter are entirely subject, whenever they are embraced within its sphere of action. By means of this superior principle, we are enabled to explain the phenomena of the organised creation and of the human economy; but without reference to it we are lost in the mazes of vague hypothesis and groundless supposition.

It has been objected to the existence of this principle, that we cannot demonstrate it to the senses in any form unconnected with matter. But we are not contending for the existence of a principle which is material, according to the received notions respecting matter, otherwise

there would be at once an end of the argument. It is, therefore, no evidence of the non-existence of this principle, that it does not become visible to our senses in an uncombined form: it is, however, sufficiently demonstrable by its effects, in alliance with matter, in which state it presents proofs of its existence equal to those from which we infer the existence of matter itself.

From these, and many other considerations that might be adduced, we conclude that life is a first principle in nature; that it exists in various degrees of energy, and in diversified conditions and forms, throughout her domains; and that these diversified states of vital existence are continued, as far as the operation of extraneous causes will admit, by a specific process, which gives rise to the production of similar beings by means of ova and germs.

It will be perceived, that the generation by which vegetable and animal bodies are perpetuated involves the belief that the ova or germs convey an emanation from the parent of a specific portion of vitality.

As, however, we can form no just conceptions of such a principle but by its effects, and as we have no experience of these effects unconnected with matter, so we are warranted in the conclusion, that the vital influence is associated with the molecules of matter forming the impregnating secretions and the sensible bulk of the ovum. This is its lowest state of activity or energy; and its influence is chiefly manifested, under such circumstances, in preserving the elements of matter with which it is associated from entering into the combinations to which the chemical affinities of these elements dispose them.

The hibernation of animals present this principle also in its lowest degree of activity: in either case, and indeed under every circumstance, it is acted upon and excited to an exalted state of existence by most of the active agents in nature. The electric fluid, heat, and other powers, have this effect, while some appear to produce a contrary impression.

The manner in which several of the active agents of inorganic nature thus influence the energy of the vital principle, appears to have been the chief reason why these powers have been substituted for vitality itself.

We have stated that the manifestations of this principle throughout the vegetable and animal kingdoms present considerable difference in degree. Its character in the vegetable creation is more uniform, and its phenomena more simple. We perceive in this kingdom, under circumstances which furnish the usual stimuli, that the vital operations of digestion, circulation, respiration, and assimilation, go forward. As soon, however, as the exciting causes are withdrawn, this principle subsides to a state of less activity; and the integrity of such organs and textures as are necessary to the growth and propagation of the species, is merely preserved by its influence until a returning impulse excites its energies.

As we advance in the scale of the animal creation, the operations of this principle become more distinct and numerous, and the mechanism provided for the performance of them more manifest and complex. As they are performed in man and in the more perfect animals, may be gathered from the body of the work and the notes which follow.

OF THE NERVOUS SYSTEM IN THE LOWER ANIMALS.

(Note B. See pp. 10, 139.)

The lowest order of animals, as the polypi, &c. has usually been considered to be destitute of a nervous system. This, however, is not the case. If we look narrowly into the structure of the lower animals, we shall find that even the lowest offers traces of a nervous system; and as we rise through the scale of the animal creation, we shall find this system becoming more and more perfect in its state of existence, and presenting appearances of perfection in proportion to the number and extent of functions which the animal is capable of exerting. Even the polypus, the lowest of the animal kingdom, seems to possess a nervous system in the simplest state of existence. If this apparently homogeneous animal be examined with a powerful microscope, numerous globules, entirely resembling those seen in the nervous system, appear disseminated throughout its structure. As a result of this simplicity of conformation, it presents no perfect manifestation of sensibility and contractility. It is not constituted of separate textures and organs, destined to perform specific purposes; and, consequently, as no relation or bond of union is requisite between its parts, as in those animals which have particular organs or structures executing particular offices; and as each of its individual parts performs the functions of the whole animal,—so its nervous system is disseminated throughout its structure, without being arranged into cords of communication or centres of reinforcement, as in those animals which, endowed with distinct organs and perfect functions, possess both.

As we rise in the scale, on the contrary, we perceive in the more perfect, and in the highest animals, the intimate texture of the nervous system, arranged so as to form communicating cords between organs which are distantly separated from each other; and not only are they provided with these, but each viscus frequently possesses, in addition, a separate nervous centre, on which the functions performed by that viscus depend: whilst the former arrangement is calculated to preserve a reciprocity of action —a mutual dependence of parts and of functions, the latter generates a vital influence modified in kind and in degree to the part which it actuates; which influence, in conjunction with what the organ may receive from a common centre, and what may be generated in the nerves of its own structure, is exerted in the production of the functions of which the conformation of the organ is but the mechanical instrument. Thus the vital influence is furnished to the different viscera in proportion to, and suitably with the nature of, its expenditure in the more complex and more complete exertion of the operations which each of them is destined to fulfil.

Respecting this subject, therefore, the following propositions may be stated:—That according to our own observations, as well as those of Prochaska, the Wenzels, Bauer, and Edwards, corpuscles or globules, entirely similar to those of which the nervous system is composed, are found disseminated, without any regular order, throughout the apparently homoge-

neous structure of the lowest order of the animal kingdom: that, as we rise in our observations through the scale of animals, we perceive this dissemination of the nervous corpuscles existing only in the mucous structures; and, as the animal presents separate organs destined to the vital operations, so these nervous corpuscles are disposed into cords of communication, and we observe a distinct nervous mass or masses, each organ possessing in addition — the higher that we ascend in the scale more especially — a detached but dependent nervous mass or ganglion of reinforcement, which varies in form, appearance, and connexion with other organs, or with other parts of the same system, according to the functions which it is destined to actuate. — See the notes on Generation, and on the Developement of the Textures of the Body, for some farther remarks illustrative of this subject.

OF THE PRIMARY SOLIDS AND COMPOUND TEXTURES OF THE BODY.

(Note C. See p. 13.)

The intimate or elementary constitution of the animal textures has long engaged the attention of anatomists and physiologists. As researches respecting this subject can only be prosecuted by means of the microscope, the results must, therefore, be received with some degree of reservation, unless they coincide with the observations of former inquirers, or be confirmed by subsequent observers. From amongst those who have engaged in this species of investigation, J. F. Meckel is entitled to much confidence, on account of his talents and industry; and the results of his labours claim particular notice, as they confirm much that has been recorded by former observers.

According to the views of this physiologist, the solids and fluids of the human body may be reduced to two elementary substances: the one is formed of globules, the other of a coagulable matter, which, either alone or united to the former, constitutes the living fluids when it is in the liquid state, and gives rise to the solid tissues when it assumes the concrete form.

The globules present, in their nature and aspect, differences which are relative to the situations in which they are examined. They appear in the blood flattened, and composed of a central part which is solid, and of an exterior portion which is hollow and vesicular. Those found in the kidneys are smaller than those of the spleen, and the globules of the liver are still smaller; those contained in the substance of the nerves present a less volume than those observed in the blood.

Globules exist not, according to Meckel, in the proper structure of the cellular tissue, of fibrous and cartilaginous parts, and of the bones. On the contrary, they abound in nerves and muscles, and determine their nature and colour. Some of the fluids, also, as the urine, contain no globules, whilst they are abundant in the blood, in the chyle, the lymph, milk, &c.

During the first period of conception, the mucous and homogeneous mass which constitutes the embryo contains no globules; it is not until a more advanced period that it is composed of two substances, the one fluid the other solid. These two elements seem to influence the form of the fibres and plates in which animal substances are disposed. The laminated tissues arise almost exclusively from the fluid matter. The fibrous tissues may also be produced from this matter alone, as in the tendons, &c.; they are, however, more frequently formed from the union of the globules with the concretive fluid, as may be observed in the nervous and muscular textures.

These observations of Meckel respecting animal organisation, it ought to be noticed, bear a near resemblance to the opinion entertained by Pfaff, who considered the elementary tissues to be formed from a series of molecules and globules, and to be different according to the presence and influence of the latter form of matter. The idea of an animal fluid, capable of concretion, is analogous to the opinion of the ancients respecting the substance denominated by them *gluten*. It is the cellular tissue, according to Meckel, which represents that substance; and, in fact, he regards this tissue as a species of concrete fluid, possessed of the properties already indicated.

It must, in our opinion, be admitted, that the theory of Meckel possesses claims to a favourable notice. It is the result of observations which accord with those of others; it is also simple, and is easily to be reconciled with the phenomena which living textures present.

Dr. Meyer, of Bonn,* also considers that two kinds only of elementary textures exist in animal bodies. The *one* is, according to him, composed chiefly of capillary vessels, and is formed from the assemblage of these vessels; under it he arranges cellular, serous, fibrous, and mucous tissues: the *other* possesses a proper and peculiar parenchyma, composed of globules, or of an organic pulp; such are the glands, the bones, muscles, nerves, the brain and spinal cord. The *first* set of organs is a continuation, in his opinion, of the vascular system; while the *second*, on the contrary, is farther removed from such a connexion. Foreign substances introduced into the circulation pass immediately, and with rapidity, into the *former* textures; while they either fail altogether in penetrating, or insinuate themselves much more slowly, and after quite a different manner, into the parenchyma of the *latter* organs. The *one* class seems to appertain in general to the system of secretion; the *other* class of textures neither secrete from their own individual influence, nor can they of themselves add to their nutrition. The *first* appears to be nourished by the immediate, rapid, and continual access of the fluid part of the blood; the *second* by a slow and periodic deposition, and conversion into their proper substance, of the sanguineous globules of the blood, by means of the influence of the vascular extremities upon the blood which they contain.

The primary solids, or rather the elementary† fibres of the human body, and of the higher

* *Journ. Complém. des Scien. Méd. Nov.* 1821.

† It should be kept in recollection, that *fibre* is used as signifying an elementary animal substance;—*tissue* indicates a certain arrangement of the former—a peculiar structure of parts;—and *organ* signifies a compound or complex part which performs functions peculiar to itself.

classes of animals, cannot be considered with propriety to be more than three—the *cellular* or *laminar*, the *muscular*, and the *nervous*.

1st. The *cellular* fibre is the most essential to animal existence, and is found in every individual of this kingdom. It consists of an assemblage of minute laminæ and delicate filaments. It is neither sensible nor irritable, and is chiefly composed of a nearly concrete gelatine.

2d. The *muscular* fibre is not so generally distributed throughout the animal kingdom as the former, for it is not found in the zoophytes.

3d. The *nervous* or *medullary* fibre. The nature of this tissue has been the subject of much investigation. M. de Blainville thinks that it originates in the muscular fibre, as this latter takes it origin in the cellular substance.

To these fibres Professor Chaussier has added a fourth, namely, the *albugineous* fibre, which is satiny, white, and very strong; and is neither sensible nor irritable. The majority of anatomists, however, consider it as merely a very condensed variety of the cellular fibre.

These fibres may be called the *first order of solids*, as they serve to form all the other tissues and organs of the body. The cellular substance, for instance, is spread out and condensed into membranes, or rolled up in the form of vessels; muscular fibres also assume the form of membranes, concur in the formation of vessels, and constitute muscles; nervous fibres produce the nerves, &c. Finally, those primary solids associate in various forms, and give rise to the compound solids, as the bones, the glands, &c.; and even to those of a more complex nature, as several of the thoracic and abdominal viscera. Indeed, every species of solid has for its base cellular substance, which is penetrated by nerves and vessels. The viscera, for example, are of this nature, having, moreover, membraneous envelopes. The bones also consist of a similar texture, and of a deposition of phosphate of lime in their cellular substance.*

Those *primary solids*, or most simple anatomical constituents, which we have just now particularised, associate in various forms, giving rise to *compound solids* or tissues, which are characterised not only by their form and nature, but also by the functions which they perform.

These animal textures or compound solids were first arranged with any degree of accuracy by Bichât; and however successful future researches into their ultimate nature may be, or whatever classifications may be proposed by future inquirers, he is still entitled to the honour of having introduced a philosophical analysis into anatomical and physiological science. The arrangement of the tissues which this great man adopted is as follows. The *exhalent, absorbent, cellular, arterial, venous, nervous of animal life, nervous of organic life, osseous, medullary, cartilaginous, fibro-cartilaginous, fibrous, muscular of animal life, muscular of organic life, mucous, serous, synovial, glandular, dermoid, epidermoid, and corneous or pilous, systems.* The exhalent, absorbent, cellular, arterial, venous, and nervous systems, he considered as being the frame-work of the body, and as *generating* the other structures, which he denominated the *compound* tissues.

M. Dupuytren has lately proposed another classification, possessing some advantages over that of Bichât. He has reduced the number of textures or systems to twelve, viz.—the *cellular*; the *vascular*, subdivided into arterial, venous, and lymphatic; the *nervous*, divided into that of the ganglions and of the brain; the *osseous*, the *cartilaginous*; the *fibrous*, comprehending the fibrous proper, the fibro-cartilaginous, and the dermoid; the *muscular* of voluntary and involuntary motion; the *erectile*; the *mucous*; the *serous*; the *corneous*, embracing the pilous and epidermoid tissues; and the *parenchymatous*, forming the viscera, and including glandular structures.

M. Beclard† admits but ten systems: the *cellular* and *adipose*, the *serous* and *synovial*, the *tegumentary surfaces*, comprehending the skin and mucous membranes; the *vascular*, the *glandular*, the *ligamentous*, the *osseous*, the *cartilaginous*, the *muscular*, and the *nervous*.

J. F. Meckel‡ also admits but ten animal structures: the *cellular* or *mucous*, the *vascular*, the *nervous*, the *osseous*, the *cartilaginous*, the *fibrous*, the *fibro-cartilaginous*, the *muscular*, the *serous*, and the *dermoid*.

M. de Blainville§ considers that the animal structures amount to sixteen, of which nine are produced from the cellular fibre, three from the muscular fibre, and four from the nervous fibre. In the *first* division he arranges the *dermoid, mucous, fibrous, cartilaginous, osseous, serous, synovial, arterial*, and *venous* (embracing the lymphatics) systems. Under the *second* division he places the *sub-dermoid* or *voluntary muscular* system, the *sub-mucous* or *involuntary muscular* system, and the *heart*. To the *third* division he assigns the *pulpy ganglial system*, the *non-pulpy ganglial system*, the *nervous system of animal life*, and the *nervous system of organic life*.

Professor Mayer has recently adopted a classification of the animal textures or compound solids, founded on his views respecting the elementary fibres or primary solids. He recognises only *eight* systems, viz. 1st, the *lamellated tissue*; 2d, the *cellulo-filamentous tissue*; 3d, the *fibrous system*; 4th, the *cartilaginous tissue*; 5th, the *osseous tissue*; 6th, the *muscular fibre*; 7th, the *glandular structure*; and 8th, the *nervous tissue*.||

The arrangement of solids which we would propose is nearly the same as that given by us at another place.¶ Proceeding analytically, we would divide the compound solids of the body into four classes, viz. *complex structures, particular textures, general systems*, and *elementary fibres or solids*.

I. Complex or Associated Structures.—1st the *digestive organs*; 2d, *organs of absorption and circulation*; 3d, of *respiration and assimilation*; 4th, *organs of secretion and excretion*; 5th, *organs of motion and of sensation*; and 6th, *organs of generation*.

II. Particular Textures.—This class includes, 1st, the *mucous textures*; 2d, *serous textures*; 3d, the *fibrous textures*, embracing the

* See Adelon's Physiology, vol. i. p. 108.

† *Anat. Générale*, p. 100, *et seq.*

‡ Manual of Descriptive, General, and Pathological Anatomy, vol. i. p. 22, *et seq.*

§ *Princip. d' Anat. Comp.* t. i. p. 13, *et seq.*

|| *Bibliothèque Germanique*, No. viii. t. 2.

¶ London Medical Repository for July 1823

fibrous, the fibro-cartilaginous, and the dermoid; 4th, the *cartilaginous textures*; 5th, the *osseous textures*; 6th, the *erectile textures*; 7th, the *glandular textures*, including the parenchyma of the viscera; 8th, the *corneous textures*, embracing *A*, the pilous, and *D*, the epidermoid textures.

III. General Systems.—Under this class we would arrange, 1st, the *cellular system*; 2d, the *nervous system*, which comprehends two orders, viz. *A*, the involuntary or ganglial order of nerves, or the system of the great sympathetic, and *B*, the voluntary order of nerves; 3d, the *muscular system*, which also embraces two orders, *A*, the involuntary order of muscular fibres, *B*, the voluntary order of muscular fibres; 4th, the *vascular system*: this system has four orders, viz. *A*, the arterial order of vessels; *B*, the capillary order; *C*, the venous order; *D*, the absorbent vessels, including *a*, the lymphatics, and *b*, the lacteals.

IV. Elementary Solids or Fibres.—1st, the *cellular fibre*; 2d, the *muscular fibre*; and 3d, *nervous corpuscles and fibres*.

Proceeding synthetically, we may arrange all the solids of which the animal body is composed after the following manner:—

CLASS I. ELEMENTARY ANIMAL SOLIDS.

The cellular fibre.
The muscular fibre.
The nervous fibre.

CLASS II. SECONDARY OR COMPOUND ANIMAL SOLIDS.

Order I. General Systems.

The cellular system.
Including the adipose tissue.

The nervous system.
A. The involuntary or ganglial order of nerves, or system of the great sympathetic.
B. The voluntary order of nerves.

The muscular system.
A. Involuntary muscles.
B. Voluntary muscles.

The vascular system.
A. Arterial vessels.
B. Venous vessels.
C. Absorbents.
a. Lymphatic absorbents.
b. Lacteal absorbents.

Order II. Particular Textures.

Mucous textures.
Erectile textures.
Serous textures.
Fibrous textures.
A. The fibrous.
B. Fibro-serous membranes.
C. Fibro-cartilaginous textures.
D. The dermoid textures.
Glandular textures.
Cartilaginous textures.
Osseous textures.
Corneous texture.
A. The epidermoid.
B. The pilous.

CLASS III. ASSOCIATED OR COMPLEX ANIMAL STRUCTURES.

Order I. Organs of Nutrition.

Digestive organs.
Organs of respiration and assimilation.
Organs of absorption and circulation.
Organs of secretion and excretion.

Order II. Organs of Relation.

Organs of sensation. *Organs of voluntary motion.*

Order III. Organs of Reproduction.

Organs of generation in both sexes.

Dr. Craigie* has lately given a different enumeration of the simple tissues, which he describes in the following order:—filamentous or cellular tissue, including cellular and adipose membrane, artery and vein, with the capillary and erectile vessels; lymphatic vessel and gland; nerve, plexus, and ganglion; brain; muscle; white fibrous system, including ligament, periosteum, and fascia; yellow fibrous system, including the yellow ligaments; bone and tooth; gristle or cartilage; fibro-cartilage; skin; mucous membrane; serous membrane; synovial membrane; compound membranes, as the fibro-mucous and fibro-serous; and the peculiar matter which forms the glandular organs.†

OF SENSIBILITY AND CONTRACTILITY.

(Note D. See p. 14.)

Sensibility.—The phenomena classed by the author under this property of animal life, at p. 14 and 15, are evidently referrible only to organic contractility, with which all classes of animals are endowed, and which, in the lowest orders and in some vegetables, assume the appearance of sensibility. In these, however, we have no reason to infer the presence of sensibility, merely because they contract under the influence of a stimulus; for the contraction may take place without the existence of this property, from the effect produced by the stimulus upon the organisation of the contracting part. Indeed, we cannot suppose that sensibility is present where the parts generally observed to be instrumental in its production are not found to exist: a sensation cannot be supposed to be produced where there neither is an organisation suitable to receive, a channel to convey, nor an organ to perceive an impression. We should, therefore, limit this term to those phenomena which the author arranges under that of *perceptibility*.

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* Elements of General and Pathological Anatomy, Edinburgh, 1828.

† In the account given by Dr. Craigie of the various arrangements of the animal textures proposed by anatomists, he has quoted the one proposed by us in the first edition of our notes, but, by mistake, has attributed it to M. Richerand, whose classification is in every respect different, if indeed it may be considered as an attempt at classification at all.

With this limitation, *sensibility* may be called the function of sensation, and a property peculiar to the animal kingdom. The sensations are derived through the medium of the senses and of the nerves, which are distributed to certain parts of the body, and which communicate with the encephalic centre. On this centre the existence of sensibility chiefly depends; the ramification of its nerves, or the subordinate portions of it, being also parts of the apparatus requisite, but not giving rise to this property. As we ascend in the scale of creation, and as we perceive the senses and the organs of volition in more intimate relation with this nervous mass—the encephalon,—so we find sensibility becoming more perfect, until in man it reaches an extent greatly surpassing that in which we observe it in any other animal.

In man, and perhaps in the more perfect animals, the *modes* of sensibility seem to vary. These modes may, however, be divided into two conditions, as they are more or less active; namely, conscious or active sensibility, and inconscious or passive sensibility: the former relates to those impressions, either from within or from without, which give rise to perceptions or ideas; the latter to those that are frequently produced upon the senses and upon the ramifications of the cerebal nerves, and, owing either to habit or the want of due attention to them, are not perceived by the mind. In this latter mode of sensibility, the organ receiving, and the channel conveying the impression, perform their offices; but the mind either is not, at the time when the impression is made, in a state to receive it, or receives it so imperfectly, from its weakness or its transient nature, as not to give rise to consciousness. This mode does not necessarily imply a difference in the degree of sensibility, but the condition in which this property exists, owing either to its being more excited by other impressions, or to its being exhausted at the time when the impression is made. This condition is one to which the highest manifestations of sensibility as well as the lowest may be occasionally subject: it is, however, merely a relative mode of this property; and the relation subsists extirely between the state of the cerebral organ which perceives, and the force and duration of the impression made upon the organ of sense. Thus, when the sensibility is actively occupied with a particular object, and an impression is made at the same time upon a different organ from that through which the perception with which the mind is engaged was conveyed, the second impression may affect the senses in an evident manner, and even so as to influence volition, yet we may be unconscious of its operation, and no active perception may result from it. If, however, the second impression be stronger or more vivid than the first, or if, from various other circumstances, it should excite the cerebral functions, active sensibility or consciousness is the result.

As sensibility, according to this view of the subject, is, in its *active* state, a term merely expressive of consciousness in the wide range of this very generally diffused faculty of the nervous system; and as this faculty is evidently dependent upon this system, especially on that more complex part of it which holds relation with surrounding objects; and, also, as we have no reason to attribute the possession of this part of the nervous system to the very lowest orders of animals, particularly to the class *radiatæ*,—so we must conclude that, although sensibility is a property of animal life, its higher grades are not possessed by all animals. It may be also stated, that active sensibility, being considered as expressive of the consciousness of the whole class of sensations, and of all the intellectual and moral operations, varies in its extent throughout the animal kingdom, according as those manifestations are more or less numerous and perfect. How far the *passive* mode of sensibility, or that unattended by consciousness, may be a property of the lowest orders of animals, is difficult to say. We may, however, infer, that as this condition of sensibility may take place without an active exertion of this property in the highest animals, so it may result from a less perfect endowment of sensibility in the lower; and as this mode may require a less complex apparatus for its production, inasmuch as its relations are more simple, so it may be possessed by animals whose organisation and manifestations do not permit us to conclude that they are capable of evincing sensibility in its more perfect and active conditions. The relations which this form or mode of sensibility holds with the numerous instincts of animals, must be evident to all who consider the subject. The relations, however, which evidently subsist between that form of sensibility called organic sensibility by Bichât, and the animal instincts, are much more numerous, more intimate, and more apparent.

Organic sensibility refers to those sensations which are produced in different degrees of intensity, owing to the existence of certain conditions of those viscera which are immediately subservient to the preservation of the individual and the species—to nutrition and reproduction, and which are not immediately subjected to the influence of volition. The conditions of the parts exciting sensibility are very various, and are the result of irritations arising from the presence of a stimulus, of unnatural actions supervening in particular systems or textures, and of the deficiency of that stimulus or influence to which particular viscera have become accustomed. Many of the changes preceding this class of sensations seem to interest, in the first instance, the ganglial class of nerves; but, owing to the intimate relation subsisting between this part of the nervous system and the voluntary or sentient part, the impression or change is propagated to the brain. This is the only essential difference which exists between this and the other forms of sensibility. It is the brain which perceives in them all; and although stimuli, or the defect of stimuli, may give rise to certain phenomena possessing the characters of the higher manifestions of this property in the organs appropriated to the preservation of the organic system, independently of the sensorium,—consciousness, or the more perfect form of sensibility, cannot form part of the results.

Organic sensibility may be active or passive—it may or it may not be attended with consciousness; and even the unconscious mode of it may indirectly impel to action, or give rise to many of the manifestations or instincts which characterise the lower animals, owing to the ganglial centres, either from their organisation or connexions, or from both, performing a greater extent of function than usually falls to their share. If, therefore, the passive form of organic sensibility may propel to action without con-

sciousness, or the sensorial sensibility being excited, in these animals, we may also account in the same manner for many of the instinctive functions being performed when we cannot trace them to the influence of a cerebral organ. Of all the conditions of sensibility, the active organic form is the least under the control of the mental powers. It also, in all its modes of existence, more intimately interests the existence of the individual than the other forms of sensibility,—organic sensibility involves a feeling in all its active manifestations instinctive of life or death.

From this it will be readily seen how close a connexion exists between organic sensibility and the animal instincts: it does not belong to our plan to trace the connexion in all its relations.

Of sensibility generally we may observe that, in the human species, it is very variable; in some persons it is very much exalted, in others very obtuse. It is vivid in early life and in youth; after the age of manhood it gradually diminishes; as old age advances, it decreases rapidly; and in persons who have attained a greater age, it is present in the lowest grade in which we find it in the species.

Contractility is essentially a vital phenomenon, and is the result of a change in the relative position of the molecules composing the solids of a living body. This property may be divided into the following grades, commencing with the lowest, it being the most generally diffused throughout nature:—

1. *Insensible organic contractility*, or that usually denominated *tone* or *tonicity*. This grade of contractility is not confined to the animal kingdom; it is a property of vegetables, and of animals not possessed of a heart. It is diffused throughout the tissues. The vascular system possesses it in the most eminent degree; and it may be viewed as the result of the vital influence with which the structures are endowed: it is more or less perfect as the vital energy is perfect, and it disappears with the extinction of this principle. It is a property of the tissues and of the vessels, which is more or less exerted in all the vital operations — in the circulation, the secretions, nutrition, and absorption. The ganglial or organic class of nerves seems to be instrumental in its production and preservation in the animal kingdom.

2. *Sensible organic contractility* or *irritability* is that inherent property of contraction which exists in all muscular and in some other textures. It is excited by the application of a variety of irritants. It seems to depend upon the ultimate distribution of the nervous substance to these parts, and chiefly upon the nerves proceeding from the ganglia.

Both these species of organic contractility seem to result from one species of influence, with which animal bodies are endowed — they are the proximate result of vitality, and merely differ from each other owing to the intimate structure of the parts in which they are seated, and to the extent to which each of the parts evincing their presence is supplied with ganglial ramifications.

3. *Cerebral contractility* is the contraction occasioned by the will in voluntary muscles. It takes place only in such muscular parts as have nerves proceeding from the encephalon, or rather from the medulla oblongata and spinal chord, terminating in their structure, and is the result of this conformation and connexion with these large nervous masses.

The first and second species of contractility result from the ganglial distributions and influence, the third from the superaddition of the nerves of voluntary motion.

Whilst, therefore, *sensibility*, in its more perfect grades, is the function of the sensations, is chiefly confined to certain parts and textures of the body, and is dependent upon the part of the nervous system of which the encephalon is the centre, *contractility* exists throughout the whole animal structures, although in different grades, and is, with the exception of the third species or grade of its existence, entirely independent of sensibility and volition; — contractility is a general expression of life, sensibility of the higher functions only of this principle.

OF SYMPATHY.

(Note E. See pp. 24—26.)

Baglivi attributed the sympathies to membranous connexion; Bordeu to the cellular tissue; Willis and Vieusens to the agency of the nerves; and Whitt and Broussais chiefly to the brain. Rega divided the sympathies into those of *sensibility* and those of *contractility*—a division which has much to recommend it. Bichât offered some very excellent observations on the relations subsisting between them and the different parts of the nervous system; but, although these observations were calculated to lead to a more correct arrangement of the sympathies than had been formerly offered, it has not come to our knowledge that any has appeared founded on a better basis than that indicated in the observations of Bichât.

In the note at p. 26, we suggested that the sympathies should be arranged into the *reflex* and the *direct*; the former arising through the instrumentality of the sensorium, the latter taking place independently of it, through the means of the ganglial nerves, and chiefly of those which are distributed to the blood-vessels, and which form communicating chords between the viscera.

With a view to the illustration of the latter class of sympathies, viz. those which are direct, and chiefly consist of the sympathetic actions of organic life, we shall offer a few remarks.

When it is considered, that the ganglial nerves alone supply the blood-vessels and the secreting organs and surfaces; that they accompany these vessels to the utmost limits of their ramifications; that they communicate very freely with each other, and with their chief centre, the semilunar ganglion; that they give rise to numerous plexuses, which render the connexion between them still more intimate; and that they hold a close relation with the rest of the nervous system, through means of communicating nerves;—the mutual dependence of action between the chief organs of the body, in health and in disease, may be easily explained. If, moreover, it be granted that the most important vital phenomena, as digestion, assimilation, circulation, secretion, animal heat, generation, &c. (*see the Note on the functions of the ganglial system*,)—in short, that life itself, with all those manifestations of it now particularised, and which have been usually called

organic, results from the influence exerted by this part of the nervous system, through the instrumentality of the vessels upon the fluid they contain, and in some measure reciprocally by this fluid upon these nerves ramified in the parietes of the vessels, and upon the ganglia themselves, through which it must of course circulate,—the agency of this system in the production of the class of sympathies under consideration must be evident. From this view of the subject, and from taking into account the modifying operation of similar textures, the related action of various organs, and, under certain circumstances, the combined influence and re-action of the sensorium, the numerous relations and connexions of healthy function and of disordered action may be more satisfactorily traced.

When one organ or system of parts is excited to increased action, or when its operations are diminished or obstructed, we perceive all the other parts of the system which communicate with it through the medium of the ganglial system, experiencing a modification of their functions, — the action of one or more organs having always an evident relation to the kind and degree of action going on in the other. In these cases the relation is sufficiently manifest; but the kind and degree of it may vary very greatly between different organs. And the relations may be of the following sorts, as the vital energies distributed throughout the system are affected in degree or in kind, or in both ways at the same time.

I. *Organic sympathies, in which the vital energy of the system evinces various modifications in degree and distribution, but in which it is not changed in kind.*

1. Related actions may be characterised by a due proportion or a healthy degree of the vital forces of the whole system; but, owing to the application of an exciting cause to one organ or part, or to two or three organs, these forces may be greatly increased in them; as, however, the healthy, or medium quantity of the vital forces of the body is not supposed to be exceeded, there consequently must be a diminution of these forces throughout the other parts of the system,* in proportion to the increase in the excited organs.

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* When the natural functions of one organ are simply excited, without being diseased, the functions of other organs with which it holds communication, by means of the ganglial nerves, undergoes a relative degree of change, — for the excitement of a viscus is merely an exaltation of its vitality; and, as we exalt the vital actions in one or more departments of the entire series, we diminish them throughout the rest in an equal proportion; the excitement being frequently greater or less in some parts, and the diminution more or less confined to others.

If, for the sake of illustration, we suppose the vital energies of the system to be equal to 50; and, through means of the organic or ganglial nerves to be distributed as follows;—to the stomach and intestines, 7; to the heart, vascular system, and lungs, 8; to the brain and voluntary nerves, 7; to the liver, spleen, and pancreas, 6; to the generative organs, 3; to the urinary apparatus, 4; to the surface of the body, 3; to the rest of the body, 11; we may consider that it is duly proportioned. But if, owing to the application of certain excitants to one or more organs, as to the stomach and intestines, we exalt the proportion bestowed on these to 13, we shall consequently find the brain and voluntary nerves possessing only 5; the heart, vessels, and lungs 7; the urinary organs 3; the surface of the body 2; and the rest of the body experiencing the loss of the remaining one. If, again, we excite the vital forces distributed to the heart and vascular system until they amount to 16, we shall have a febrile condition of the system in its simplest form, and all the other organs will suffer a diminution in proportion: the stomach will only equal 4, and so on in proportion. But the vital forces of the heart and blood-vessels may equal 16; and, owing to the arteries of the brain experiencing an undue proportion of this increase, this organ may at the same time equal 10; or, instead of this increase falling to the lot of the cerebral vessels, those of other viscera may be similarly augmented, whilst those of the remaining organs may be proportionally diminished: in such cases we have a less simple result; but, nevertheless, the increase of the circulating functions is followed by an equal diminution of the secreting. Viewing the sympathetic connexion of function in another direction, we shall suppose that the excited state of vital action takes place in secreting organs: in this case the nutritive and other animal operations are diminished in an equal degree. Or we shall suppose that the excitement commences in the capillaries of an organ, from the presence of an irritating cause; that, owing to these vessels being supplied with ramifications of the same order of nerves which supply the heart and vascular system generally, the excitement extends more or less throughout this system; and that, in consequence of the continuity of this order of nerves, and their very frequent reticulations and inosculations, not only do the heart and arteries experience the excitement produced at a part of the extreme circumference, but the whole body suffers a relative degree of derangement, and hence evinces all the phenomena of sympathetic fever. Thus, the capillaries of a particular organ are excited; the excitement extends more or less generally throughout the vascular series, and the nutritive and secreting functions are diminished in proportion as the actions of the heart and arteries are increased. Many collateral views of this subject may be adduced, and many of its connexions traced, as well as various modifying influences, both in and out of the body, appreciated — all tending to establish the position, that it is chiefly to the ganglial nerves we ought to attribute the manifold phenomena of related action which we observe in the animal economy. At this place we have only considered one of the genera belonging to this class of sympathies, namely, that which comprehends the most simple of the related actions — those which supervene in the system without an increase or diminution of the whole amount of the vital energies with which the body is endowed. The other kinds of related function have been pointed out in the above arrangement of this class of sympathies, and we cannot farther allude to them here; indeed, it would be much beyond our limits to consider

In this order of sympathies there are three relations to be observed, which actually more or less obtain and constitute the essence of the subject, or the actual condition of the animal functions under consideration. 1st, the relation may respect the increased actions subsisting in two or more organs; 2d, it may be viewed between the increased functions of one part and the diminished functions of another; and 3d, it may regard the diminished functions observed in those parts which do not participate in the excitement; the relation being most immediate in the first, and least so in the third of these forms.

2. The sympathetic or related actions may be attended with a diminution of the sum of the vital energies throughout the system. In this case the different relations pointed out above may nevertheless exist, or one or two of them only may be remarkable; the chief difference here being that the sympathies of this order are generally induced by agents, which, while they diminish the entire sum of vital energy, act more decidedly upon particular organs or systems of parts.

3. The sympathetic operations may be characterised by a somewhat greater amount of the vital energies of the whole body. In this order of sympathies the three relations particularised above also subsist; for although the entire sum of vital actions may be greater than what is usually bestowed on the system, it may be so much increased in some organs as to be greatly diminished in others. This condition of functional sympathy seldom continues long, until it subsides to the first, or, from exhaustion of the vital energies, to the second order just now particularised.

II. *Organic sympathies in which, in addition to various modifications in degree and distribution, the vital energy of the system suffers a change in its kind.*

1. Sympathetic actions in which the general amount of the vital forces is natural in degree, but vitiated or modified in kind, the relation being evident—1st, mutually between those functions which are increased; 2d, between the actions which are augmented and those which are diminished; and 3d, between those only which are diminished.

2. Sympathies in which the entire sum of vital energy is both reduced in degree and modified in kind; the relation between its distribution in the various organs being the same as just now pointed out.

3. Sympathies in which the amount of the whole vital energy is both heightened in degree and modified in kind. In this order, the distribution and the relations to which such distribution gives rise are the same as already adduced.

The application of this classification, and of the views which it embraces, to medicine, must appear evident.

OF HABIT.

(NOTE F. See p. 27.)

In the note at p. 27, we have said that the effects of habit upon our voluntary organs are very different from those which result from its influence on the viscera of organic life. This difference is, however, chiefly in degree; for as sensibility, there is every reason to suppose, from its most vivid state of existence, until it merges in contractility, and in its various modes of manifestation, differs chiefly in degree, and as it is bestowed in some one mode and degree to all the organs of the body, although it be more particularly limited to one of their tissues, and also as the influence of habit is chiefly exerted upon the sensibility of the system,—so it follows that it modifies more or less all the animal and organic functions, although it acts in the most manifest manner on those organs which are in the closest relation with the sensorium or functions of the brain. Thus the stimulus which excites the action of the sensorium produces a much less intense effect by repetition; but the repeated employment of the same food, or of the same purgative, does not materially less excite the action of the viscera to which they are respectively applied. As the influence of habit, therefore, is chiefly on the sensibility of the system, so it follows, that when the organic sensibility of the involuntary organs is repeatedly excited, it is then that the diminished effects of the excitant upon them are most manifest—that the more the sensibility of our organ is called forth, the more is the influence of habit remarkable. Those stimuli, however, which act chiefly and the most exclusively on the contractility of the textures, and those organs whose actions principally consist in the exertion of this principle of life, have their operations the least impaired by repeated employment; indeed, in many instances those organs have their functions increased and rendered more perfect by frequent exertion. Hence, independently of degree, is the chief difference in the influence of habit on the voluntary and involuntary organs of the body.

OF INFLAMMATION.

(NOTE G. See p. 35.)

As the author has taken occasion to give his opinion respecting the proximate cause of inflammation, we shall follow his example, and briefly illustrate the view which we entertained of it, and published in a thesis on rheumatism in 1815, and more recently in a paper on the functions of the ganglionic nerves, contained in the London Medical Repository for May 1822. On these occasions we defined active inflammation to be the result of a morbidly excited state of the ganglial nerves supplying the capillaries of the affected part—or a derangement arising from the unnaturally exalted condition of these nerves, on which the functions of the capillaries depend.

One of the chief inquiries respecting its nature and physiological relations, is, whether this exalted or excited state of these nervous fibrilæ is one of simple excitement or no, — whether the natural functions of these fibrilæ be merely increased above their healthy or ordinary pitch, or whether or no they are also otherwise changed. In the definition, we said morbidly or unnaturally excited, thereby indicating that the

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fully the different kinds of sympathy in their manifold relations; we have illustrated one more particularly, because of its importance, and of its having been very generally overlooked.

functions or influence of these nerves are not only simply increased, but also increased differently from what we observe in a healthy part, from the application of a stimulus, both as respects duration and kind of action.

1. As respects the *duration* of this exalted state. In the vascular phenomena displayed by blushing, or by the application of a gentle stimulus, the effects soon subside after the removal of the exciting cause ; because the nervous influence exerted on the capillaries is simply increased without the mode or habitude of operation being changed. But before we can farther explain the duration of excitement, we must secondly inquire into its *kind*.

2. When a stimulus or irritant is applied to a part, its action seems to be first upon the ganglial fibrilæ supplying the capillaries. The vital influence of these fibrilæ being excited, the actions of the capillaries which they supply are consequently increased. There is, however, every reason to suppose, that the increase of this influence is not simple, that it is not only changed in degree, but also modified in kind. The irritant seems to impress the nervous fibrilæ of the part, or of the system more generally, in such a manner as to prevent it from returning to its natural state for a very considerable time, or even at all ; the excited action is induced, it continues, and the longer it continues, the less is it disposed to return to its healthy condition. But wherefore does the excitement continue? To this may we answer, either because the irritating or exciting cause continues to operate by its actual presence, or more frequently because the impression made by it, while it changed the degree of nervous influence, also modified its state of existence and kind of operation on the vessels themselves and the fluids which they contain. It is, therefore, owing to the impression of the causes or changes thereby produced in the kind as well as degree of influence exerted by the nervous fibrilæ, that we are to impute, 1st, the duration of the excitement; and, 2dly, the different phenomena which capillary derangements or inflammations present. A few of these phenomena we shall particularise.

1. *Uneasy sensation, from its lowest degree until it amounts to acute pain.*—Uneasy sensation alone may be considered one of the primary phenomena following the operation of the exciting cause ; or, rather, one of the manifestations characteristic of that kind or state of excitement or deranged influence of the nervous fibrilæ, forming the first series of the changes induced in the affected part ; and it may be farther kept up by the subsequent changes induced in the capillaries by the disordered state of the nervous influence, of which state it is itself one of the manifestations. When the uneasy sensation amounts to pain, it may be owing either to the degree of change with which the influence of the nervous fibrilæ, and through it the action of the capillaries, are imbued, or it may arise in consequence of the ganglial system of nerves communicating the disordered excitement which has commenced in them to these cerebral nerves with which they are associated in the textures : for, as we have already stated, the ganglial nerves being plentifully distributed to the capillary vessels in every part and tissue of the body, must consequently communicate freely, and come closely in contact, with the sentient or voluntary class of nerves, especially in those textures which are abundantly supplied with them. By means of this connexion, the excited function of the former class is very probably communicated to the sentient extremities of the latter class, and their sensibility, being thus excited, is still farther increased by the derangement of the capillaries which the former nerves induce. But this phenomenon of inflammation may not result exclusively in the one manner or in the other. It may take place in both ways in the same part, or in the one or the other more or less partially. In those viscera which are imperfectly supplied with the cerebro-spinal nerves, the first alternative may be adopted. Indeed, in these textures very considerable inflammation may exist without any other modification of pain than uneasy sensation being felt ; whereas in the other organs, whose supply of cerebro-spinal nerves is considerable, the second explanation may be entertained ; whilst in some viscera both modes of accounting for this morbid manifestation may be resorted to. But whatever manner of explanation should be adopted according to the distinction just now stated, it ought not to be forgotten, that this particular manifestation of disease is modified throughout its manifold grades by the texture of the part affected, and by the exciting and other causes to which it is indebted for its existence and progress.

According to this view of the subject, it will be observed, that we consider the pain of inflammation as originating in, or caused by, the condition of the particular influence or function performed by the fibrilæ or the ganglial system of nerves,—as a state of these nerves producing deranged action of the capillaries to which they are distributed, and exciting or otherwise disturbing the sensibility and functions of the other class of nerves with which they become associated in many of the textures ; whereas the most acute pains, those which are not necessarily attended with inflammation, and very seldom give rise to it,—as those accompanying tic douloureux, trismus, the various forms of spasmodic diseases, and some other painful disorders which it is unnecessary to designate,—originate exclusively in the fibrilæ of the cerebro-spinal nerves. This appears to be an important and fundamental distinction in pathology, and one which we have not adopted without much reflection and pathological research. It accounts for a very frequent phenomenon, namely, the presence of the most violent pain when there are no appearances of inflammation either during its existence or after its subsidence. It shews also that, with the exception of the countenance and one or two other parts, excitement commencing in the cerebro-spinal or sentient nerves has but little immediate influence upon the capillary circulation ; and it also points out, that whatever influence these nerves may possess over the circulation and the vital phenomena allied to it, it is only by means of exciting the ganglial nerves distributed to the structure of the part, and to the blood-vessels ramifying in it, that any such influences can be exerted. This, it might be shewn, were it neccessary to speculate respecting final causes, is a provision requisite to the preservation of the textures, and consequently of the animal body ; for if the circulation throughout the different textures and organs were *immediately* under the dominion of the sentient nerves, and removed from that of the ganglial, we

should have not only all the phenomena which more strictly belong to it, but all the vital manifestations of nutrition, secretion, animal heat, &c. which are under the influence of the ganglionic system, subjected to continual derangement from the various impulses of the will and the passions. As these functions, on which the preservation of the individual depends, are under the dominion of another and a less fluctuating influence, they are less endangered by the numerous causes of change by which they are constantly surrounded, and with which they hold frequent communication. But, although the functions which are immediately vital are those that belong to the province of this system, they may be acted upon either generally or partially, through the medium of the nervous system of relation or of animal life, which system has its own particular functions to perform, and these occasionally exert no mean influence over those of the former class.

2. ***Redness, or the injection of the capillaries with red blood.***—This phenomenon has created much discussion. It would be foreign to our plan to enter at this place upon the different arguments which have been entertained respecting it. We shall merely state our own opinion as to its nature.

The vital influence of the ganglial class of nerves is, as we have just now stated, morbidly increased in the affected part, especially as respects these nerves distributed more directly to the capillaries. We observe that on every occasion in the animal economy, when the vital actions of capillary vessels are increased, the vessels themselves become larger, more fully injected, and circulate a larger quantity of blood. Now, if we allow that an increase in degree forms one part of the change in the vital influence bestowed on the capillaries by the ganglial nerves, it therefore follows that a proportionate change in the calibre of the minuter vessels should result from such increase, as usually does on those occasions when it supervenes in a natural manner.

In short, that one of the changes constituting the acute stage of inflammation is an excited state of the vital influence, distributed by the ganglial nerves to the capillaries of the part: an excited state of this influence always increases the action and calibre of the capillaries; therefore, both these conditions must be increased whenever an excited state of the vital influence constitutes a part of the primary derangement. The capillaries during acute inflammation are in every respect in a similar state to that evinced by erectile tissues when they are excited.

But it has been argued, that when an inflamed capillary is viewed in a microscope, the current of blood in it is slower, instead of being quicker than natural. This, however, arises, as we have stated on another occasion, from the inflamed capillary vessel admitting a greater number of red globules, and thus giving rise to the optical illusion of their slower motion, when in fact they actually move much quicker than when the vessel admits a single globule at a time, and when the entire space between each globule moving in the vessel can be seen. Another objection has been urged in support of the hypothesis of relaxation or debility of the vessels, namely, that the exposed capillaries contract upon the application of an irritant; but so do all irritable parts, and so do all parts to a greater or less extent which are supplied with the vital influence. In these experiments it has not been considered, because it was unfavourable to the hypothesis, that the irritant acts in a two-fold capacity; it excites irritable fibres to contraction, and it constringes the structure of the part. These experiments also appear generally to have been performed under circumstances of disorder, and at a period when the inflammation was passing into that stage which is constituted by a greater or less exhaustion of the increased influence which formerly actuated the capillaries.

3. *Increase of the animal heat in an actively inflamed part.*—We have contended, in another place, that animal heat is the result of the vital influence of the ganglial nerves upon the vessels and the increased quantity of blood circulating through them in a given time, and that the heat of the whole body or of a single part has an intimate relation to the degree of influence which this system of nerves exerts, especially that part of it supplying the bloodvessels, either as respects the body generally, or as regards the part more particularly affected. If this position be granted, it cannot be denied that the augmented heat in inflammation is derived from the same source, namely, the increased influence, on the vessels of the affected part, of that particular system of nerves on which the production of animal heat chiefly depends, together with the circumstance, of the augmented diameter of the capillaries allowing a greater quantity of blood to pass through them; the nervous influence enlarging these vessels, or occasioning an erectile state of them, and this state soliciting an afflux of blood to the affected part. (*See the Note on the functions of the ganglionic system of nerves.*)

From this it will be seen, that we consider inflammation, in its various forms and stages, to originate in, and to depend upon, the altered kind and degree of influence which the ganglial system of nerves exerts on the capillaries of the part; that whenever this influence is greater than natural, the action of the capillaries is greater than natural, and whenever it is below the healthy condition, these vessels are equally deficient in a requisite degree of action; that the *kind* of influence is changed as well as the *degree* of influence; and that, as inflammation originates with the nerves supplying the capillaries of the diseased part, it may be considered as a lesion of the functions of these nerves, affecting the condition of the capillary vessels, and occurring more frequently in those tissues which are the least supplied with an additional and a compensating influence from the other parts of the nervous system: hence the reason that inflammation is very seldom seen in the muscular structures to which the cerebral nerves are so plentifully distributed, and hence the probable cause that it so frequently attacks cellular parts, or those which are essentially cellular in their nature and are supplied with ganglial nerves only.

At this place we have merely considered a few of the physiological relations of acute inflammation, in a brief and an imperfect manner. The other points connected with this subject which might be discussed, but which are more strictly pathological, are—1st, the different characters of acute inflammation, according to the textures in which it is seated; 2d, the stages of inflammation in relation to the individual

tissues, down through their numerous grades until they reach the lowest; 3d, inflammations in which the influence bestowed on the vessels by the ganglial nerves is more or less exhausted or destroyed; 4th, the state of the venous capillaries and absorbents in the different stages and grades of inflammation; 5th, the varying phenomena which this species of derangement presents, according as it is modified by constitutional peculiarities; 6th, the different manifestations of inflammation arising from the nature of its exciting causes, &c. These and other relations of this fundamental and most important part of pathology, will be considered in an extended manner on another occasion.

OF THE GANGLIAL OR GREAT SYMPATHETIC SYSTEM OF NERVES.

(Note H. See pp. 37—40.)

It would be incompatible with the limits of these notes to point out the anatomical peculiarities and connexions of this important system, or even to enter upon a lengthened discussion of its functions. We shall therefore confine ourselves to the statement of the general propositions at which we arrived on the latter part of the subject, and which were contained in a paper on the functions of the ganglionic system of nerves, read at the Medical Society of London in 1820.

It may be proper to remark, that these inferences were deduced from numerous dissections of individual subjects belonging to the different classes of animals, and from several experiments made in order to ascertain the extent of function which this system of nerves performs. The observations made on these occasions we shall soon have an opportunity of describing in a particular manner.

1. The ganglial class of nerves is to be found throughout every order of the animal creation, commencing with the lowest, the *Radiatæ*, and ascending to the highest.

2. The ganglial nerves are the only part of the nervous system with which the lowest orders of animals are provided.

3. As we ascend the scale of creation, another class of nerves is superadded, namely, the encephalic, with which the ganglial nerves are connected. In the higher animals possessing only the ganglial nerves, we perceive the ganglion placed on or near the œsophagus, gradually assuming more and more the characters of a brain, and becoming more evidently connected with organs of sense. We also observe the nervous chords between the ganglia arranging themselves more and more in the manner of a spinal marrow, as the locomotive organs become more distinct from those of nutrition; thus rendering the steps of gradation between the animals provided only with the lowest or simplest form of nervous ganglia, and those possessed both of ganglia and of an animal or voluntary system of nerves, almost imperceptible.

4. The nerves which are given off from the encephalic mass and from the spinal marrow evince different characters as soon as these parts of the nervous system become distinct from the ganglia; and even in progress towards the fullest distinction which they ultimately attain, the difference between both the classes of nerves becomes still more manifest.

5. In all the more perfect animals, the ganglia and their various distributions, as far as they can be traced by the senses, even when aided by powerful glasses and minute dissection, are entirely different from the nerves derived from the brain and spinal chord, in their texture, colour, consistence, mode of ramification and distribution; and they supply very different organs and textures from those to which the cerebral and spinal nerves are distributed.

6. Not only in the lowest order of animals may the ganglial nerves be traced before the voluntary or sentient class of nerves come into existence, but also in the embryos of the higher animals the ganglia may be distinguished before any traces of a spinal marrow or of a brain can be perceived.

7. The ganglial nerves cannot be supposed to originate in either the brain or spinal marrow—1st, because they are observed in the lowest animals, which possess neither brain nor spinal chord; 2dly, because they may be distinguished in embryos before either the one or the other nervous mass can be traced; and 3dly, because they are never wanting in the fœtal state,—whereas not only have the brain and spinal marrow been individually wanting, but the same fœtus has been found entirely without both.

8. The difference between this class of nerves and those of animal life, is not evinced only by their respective appearances, by the general distribution of the former throughout the animal creation, by the history of the embryal fœtus, and by the phenomena exhibited by monsters; but it is also apparent from the very different effects which are observed in them, as respects both the living and dead subject, on the application of various excitants and re-agents.*

* The difference between these nerves is very remarkable on the application of galvanism; for, whilst we found that the voluntary nerves could be excited with a few plates, two hundred could produce only a slightly perceptible effect upon the parts more immediately supplied with fibrilæ from the semilunar ganglion. When galvanism was applied to this ganglion itself in the recently killed animal, but little appreciable effect was produced either on the vessels with which it is so intimately connected, or upon the stomach and upper portion of the small intestines. In the majority of instances, however, these parts seemed to be in a more contracted state while under the galvanic influence. When the influence of the battery (of two hundred plates) was directed upon the semilunar ganglion of a young cat, it evinced symptoms of pain and distress, and several irregular contractions of the diaphragm supervened. The effects of galvanism were also tried on some of the other ganglia, but they evinced no appearance of being oppressed by it in the dead subject, and in the living the result was equivocal. On these occasions we experienced great difficulty from the want of proper assistance. We propose, however, to repeat and to extend these experiments; and we expect eminent coadjutorship in their performance, and the assistance of a very powerful galvanic battery.

9. The points of dissimilarity just now instanced evidently shew that the ganglia and their numerous distributions form an independent system in the animal economy; and that as one thing cannot be said to form a part of another thing from which it is essentially different, so the ganglia and their ramifications cannot be supposed to form a part of the nervous system of animal life, or that which presides over the intellectual and locomotive functions.

10. The independence of the ganglial system may be farther demonstrated in many of the lower animals, and in the young of the most perfect animals, for in these both the brain and spinal chord may be destroyed gradually; and, provided the function of respiration be not entirely put a stop to, the functions of circulation and secretion will still be continued.

11. That the independence of this system, and the extent of the peculiar influence which it exerts in the animal economy, is farther proven in the most perfect animals, by the effects of disease upon the brain and spinal marrow, either of which may be destroyed to a very great extent, and those organs only which they supply be deprived of their functions, while those viscera which receive the ramifications of the ganglial system will continue to perform their actions without evincing much disorder, unless that part of the nervous mass which actuates the contraction of the respiratory muscles become involved in the disease.

12. The ganglia supply with fibrilæ all the organs of digestion, assimilation, circulation, and secretion.

13. The heart is chiefly supplied with nerves coming directly from this class of nerves.

14. These nerves form a closely reticulated envelope around the arteries of the thorax and abdomen, and around the vena portæ: they may be traced in the larger branches of arteries of the extremities and of the head, until they reach the brain itself.

15. The arteries throughout the body, and indeed all the other parts of the vascular system, receive nerves directly from no other source than from the ganglia.

16. The same system supplies, in a demonstrable manner, all the involuntary muscles, and it seems to send fibrilæ to several of the voluntary muscles, especially to those about the centre of the body. It is also liberally distributed to all the secreting glands and surfaces.*

17. From the manner in which the ganglial nerves invest the arteries proceeding into the brain, and reasoning from analogy, we infer that they accompany the arteries throughout the substance of this viscus, as in other organs of the body, and that they influence its vascular functions in a similar manner.

18. The chief origin or centre of the ganglial system is generally situated, in all the higher orders of animals especially, about the middle of the body, and, under the name of the semilunar ganglion, it sends off branches which form plexuses; these present modified characters, as respects their external appearance and conformation, in their course to the different organs which they supply.

This central ganglion more immediately supplies the organs of digestion, chylifaction, and circulation, where the expenditure of the vital influence is greatest, and sends communicating branches to the subordinate ganglia and plexuses.

19. The external characters of the ganglia and of their plexuses and ramifications vary considerably in different situations, both as respects their colour, their external form, and internal structure.

20. The subordinate ganglia, while they seem to receive a reinforcement of vital influence from the centre ganglion, modify that influence, and generate an accession to it, suitable both in kind and in degree to the functions of the organs which they are destined to actuate.

21. This class of nerves send off and receive chords of communication between the brain and its subordinate organs, and between the spinal marrow and its distributions: this seems to give rise to a reciprocal communication of influence between the organs of nutrition, &c. and those of relation, and a mutual dependence of function, which is more intimate and apparent as we rise in the scale of creation,—the independence of the former class of functions becoming more evident as we descend, and the younger the animal is as we ascend the scale.

22. The extent and mode of communication between different parts of the voluntary nerves and the ganglia and their distributions vary very considerably.

23. As this class of nerves are so entirely different in their appearance, structure, properties, and mode of distribution, and as they supply very different organs from those which receive the encephalic class of nerves, so it may be inferred that they perform essentially different functions, although these functions, in the higher animals more particularly, are in close relation with those of the rest of the body.

24. As it is demonstrated, that the ganglial

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* If, therefore, these nerves are every where demonstrable in the centre of the system, and even throughout its radius, until we arrive at the superficies or extreme parts of the body, where it may be supposed that they must elude, from the nature of their organisation, the detection of the senses, it cannot be contrary to the uniform operations of nature, and to the many analogies she presents, to infer that they are distributed to the extreme ramifications of the arteries, upon whose trunks and larger branches they are readily demonstrable. And if they are also shewn to exist in some voluntary muscles, may they not be considered to be present in all, bestowing upon these muscles peculiar energies, the nerves of animal life producing the functions which usually result from this class of nerves, in addition to those arising from the involuntary influence or vital energy which these muscles derive from the ganglia and their distributions?

It may be mentioned, that, consistently with the opinions we entertained respecting the independence of, and extent of the functions performed by, the ganglia and their distributions, that we assign the terms — ganglial system, organic system of nerves, vital system of nerves, synonymously; and we use the terms—cerebro-spinal system of nerves, voluntary nerves, and sentient system, also synonymously. To this there may be some objections, but as we did so in the original paper, we wish not to alter it.

or vital nerves supply the heart; that they surround and are ramified in the arteries throughout their distribution; that no part of the vascular system receives in a direct manner any voluntary nerves; and as it is reasonable to suppose that this provision does not exist without accomplishing important purposes in the animal economy, and as the fibres of involuntary muscles are evidently supplied from the same source; and, farther, as we cannot suppose, conformably to the laws of nature, that the bare coats of the vessels, and particularly of the arteries, without such a provision could be possessed of any vital properties, — so we infer that all the vital phenomena which the vascular system exhibits throughout the body are under the direct influence of this class of nerves.

25. The distribution of these nerves around the arteries, and the manner in which their fibrilæ penetrate the coats of these vessels, seem to evince that they not only impart to them whatever vital properties they may possess, but that they moreover produce those changes on the blood to which it is subject whilst flowing in the vessels, and many of those phenomena which this fluid presents soon after it has been taken from the body.

26. It is also reasonable to suppose, that the influence exerted by this system on the capillaries, and the additional influence which its ramifications bestow on the substance of the viscera, combine to produce the secretions in secreting organs and surfaces, and nutrition throughout the textures of the body. Hence, that the varied phenomena displayed by the blood itself, by the functions of digestion, secretion,* assimilation, &c. result from the condition of the influence which this system, in its centre and distributions, is instrumental in generating in the vessels and fluids which they contain. May not a vital influence or atmosphere, as it were, be produced from the extreme fibrilæ of this system, or between them and the coats of the capillary vessels, which influence, whatever may be its state of existence, impresses the fluid circulating in these vessels in a manner which produces different effects, according to its excess or defect, or according to other modifications to which it may be subject, in health and disease, owing to the numerous causes of changes to which it is exposed?

27. The separation from the blood of the materials which supply the waste of the textures, or give rise to their growth, is the office of this system, which imparts its influence to, and operates through the medium of the vascular system.

28. The vital manifestations of veins and absorbents (with the exception of the vena portæ) arise from the distribution of the system of nerves to the minute arterial capillaries supplying their parietes, and to the adjoining textures; and, probably, from the distribution of minute fibrilæ to their tunics — an organisation which, although it cannot be demonstrated, may nevertheless exist, and thus the vital manifestations of the venous system may more readily be explained.

29. The ganglial nerves sheathe the vena portæ throughout its course in the liver; and from the very abundant manner in which they supply this particular vein, from the conformation of the vein itself both as respects its coats and connexions with the texture of the liver and with the other vessels, and from the character of the blood conveyed to and from it,— we conclude that it is through the vital influence bestowed on the vena portæ by the ganglial nerves, assisted by that belonging to the other vessels and the texture of this viscus, that the changes induced in the blood returned from the digestive canal and its allied viscera, and containing a large proportion of absorbed materials, are produced; and that the secretion of the bile results from the same influence, partly as a consequence of these previous changes, and partly as its independent act, exerted both upon the extreme ramifications of the vena portæ and of the hepatic artery, this secretion consequently proceeding from both the kinds of blood contained by these vessels.

30. That this system of nerves, by means of the influence derived from its principal and subordinate sources and numerous distributions, and exerted upon the vascular system, generates animal heat throughout the body; and that the production of animal heat takes place in a manner analogous to the processes of nutrition and secretion.†

* No experiment instituted with the intention of shewing the influence of the nerves given off from the brain and spinal chord upon secretion, can prove the reality of such influence; because these orders of nerves are not ramified upon the vascular system, nor do they even supply the capillary vessels. This is a wise provision; for if the heart and blood-vessels were directly under the influence of the voluntary nerves in any of its divisions, this system would be constantly deranged by it, and vascular disease be incomparatively more frequent and fatal. Such experiments, were they instituted with the utmost precaution, could prove no more than has been shewn by those of Dr. Phillips and M. Legallois, which, at most, evince that the vital functions resulting from the ganglial or vital class of nerves may be influenced, in the more perfect animals, by the destruction of a part of the nervous system with which they have held, and with which they always hold, a more or less intimate relation; and that the same nerves which, during health, have conveyed a natural stimulus to the vital activity of particular organs, may convey an artificial one; and when the natural stimulus or excitant is removed, or the subordinate function annihilated, the operations to which it is requisite, in the highest animals, must languish and ultimately decay.

Indeed it is only reasonable to suppose, that the involuntary nerves, as they communicate with the organic or vital nerves, convey a natural stimulus or influence to the latter, which, if they were deprived of it, after its continued and uninterrupted influx, the vital functions of the organs enjoying this additional influence would necessarily languish, or even be overturned if the privation took place suddenly and completely. If, however, it were brought about gradually, it might be produced to a great extent, and in many animals completely.

† The experiments of insulating a limb by dividing all the voluntary nerves and arteries excepting one arterial trunk, performed by Mr. Brodie, in order to ascertain the effects pro-

31. The state of animal heat, like other secretions, will be greatly modified by the condition, both as respects kind and degree, of the vital influence of the ganglial system, and by the state of the blood on which this influence is exerted, which state will have a double operation in modifying the result.*

32. It appears probable, from the effects of several agents upon the voluntary and other muscular parts, when applied immediately to the ganglial or vital system of nerves,—from the general distribution of this system to the capillary arteries,—and from the circumstance of its supplying and actuating the involuntary muscles,—that it also bestows its proper influence upon those which are voluntary, and that thus it gives rise in both to the phenomenon of muscular parts usually called irritability; the different manifestations of this property, as it is displayed in voluntary and involuntary muscles, resulting from the accessory supply of the cerebro-spinal nerves which the former class of muscles receives.†

33. That the ganglial system appears to be productive of certain obscure sensations or instinctive impulses (organic sensibility) which are, by means of the communicating branches of nerves between this system and the cerebro-spinal masses, propagated to the latter; and from the influence they there excite, become the causes of several manifestations, which more immediately proceed from this latter part of the nervous system.

34. This operation of the ganglial system on the functions of the cerebro-spinal system, is more remarkable when the former is influenced by disease or by a stimulus which is unnatural either in kind or degree; or even when a natural excitant to which this system has been accustomed is withheld, whether such excitant operates either directly or indirectly, or in both ways, as the supply of food, &c.

35. The communicating branches of nerves between the chief ganglia of the abdominal and thoracic cavities, whilst they are the medium of communication between the ganglial and cerebro-spinal systems, intercept or moderate, by means of the subordinate ganglia placed in their course, the influences proceeding from the one system to the other. Thus it is that the ganglia in the neck and chest moderate the influences of the functions of the brain on the heart, and that no impulse of the former can reach the latter but through the medium of the ganglia; and so little are the ganglia influenced by the operations and excitements of the brain, that organic sensibility is only slightly produced by them. If, therefore, the impulses of passion and volition produce but an obscure effect upon the ganglia and their chief centre, it is not to be wondered at that the galvanic influence,—which must be very considerable to equal the impulses of volition,—should act comparatively in a very slight and almost insensible manner upon this system.

36. The ganglia on the communicating branches between the internal ganglia and the spinal chord, intercept the impulses proceeding through this latter channel; and while they thus moderate the operations of both the brain and spinal marrow upon the internal ganglia, they seem to generate an influence suited to the intermediate place which they hold.

37. Irritations of the ganglial system appear to act in a slight and obscure manner upon the voluntary organs, through the medium of the communicating or conducting branches between this system and the spinal chord; and, but for the ganglia on their course, the irritations of the former, and the impulses of the latter and of the brain, would reciprocally act in a manner that would be much more marked, and even in a way that would be injurious to the whole body.

38. The influence of the ganglial on the cerebro-spinal system is more marked as the developement and functions of the former system predominate, as in the lower animals and in the fœtus of those which belong to the highest orders.‡

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duced upon the generation of heat in the limb, prove this proposition, and could not fail of giving rise to what was actually observed. For the ganglial or vital nerves supplying that vessel could not be completely detached as long as any of the coats of the artery remained undivided.

* See the Note on Animal Heat.

† See Note I I. of Appendix.

‡ The following outline exhibits a view of the extent of influence which we have attributed to the ganglionic system: it formed a part of the contents of a treatise on the anatomy, physiology, and pathology of the ganglionic class of nerves, &c. the publication of which was commenced in the London Medical Repository, but was discontinued in order that it might appear in a separate and extended form.

"Part I. comprehends the following sections:—1. A description of the organs generally called nervous ganglia.—2. An examination into the distribution of their ramifications or fibrilæ, as far as that has been demonstrated, either by my own or by the observations of others.—3. Reasons against the usually received opinion, that they constitute a part of the cerebral and spinal nerves; and proofs of their forming a distinct system from the brain, spinal chord, and nerves proceeding from these sources.—4. An account of the connexion existing between the ganglia or their ramifications and the nervous system properly so called, and the mode by which that connexion is effected.—5. An inquiry respecting what viscera and textures they supply.—6. Proofs, from the history of the species, and from comparative anatomy, that they form the first effort of organisation, and are instrumental in the production of the other textures.—7. Remarks respecting their state during the formation, progress, and decline of the animal.—8. Inferences from the preceding inquiries.

"Part II. The functions of the ganglia considered.—1. As they regard the vascular system, on which they are chiefly ramified.—A. Proofs that the ganglia are the primary and chief source of the heart's action.—B. Their power over the arterial and capillary systems inquired into, and the irritability of the latter class of vessels contended for, and shewn to be derived from this cause.—C. Evidences of their influence over the secreting viscera and textures. *a*. On the gastric secretions and functions. *b*. Their control over the secretions from mucous and other surfaces, and from follicular glands. *c*. Over the biliary and pancrea-

39. As the ganglia of the great sympathetic form an independent system, presiding over certain functions which are essentially vital, consequently they may be viewed as the system and seat of organic life, and may therefore be denominated, the vital system of nerves, whose centre is the semilunar ganglion.*

40. It seems probable, from the circumstance of a separate ganglion or plexus, or both, being generally assigned to each important secreting or animalising organ, that the centre or source of vital influence does not supply the whole vitality distributed by the ganglial ramifications to the individual organs and textures; but that the vital influence proceeding from this centre is reinforced by that which is produced by the subordinate ganglia, and is not only reinforced, but modified by them, and by their distributions in the various organs, so as to give rise to the specific difference of function which each performs; and that the vital manifestations of particular ganglia are still farther modified by the communicating branches between them and the cerebro-spinal system, the extent of modification being relative to the extent to which the nerves of this latter system either communicate with, or contribute to supply or to form, the individual subordinate ganglia.

Lastly.—The vital influence being thus produced from the centre of the body, and reinforced and modified by subordinate ganglia, allotted to the individual organs according to their functions, is propagated along the distributions of the system, on which it depends and is inherent, throughout the whole body.

APPENDIX

TO THE

CHAPTER ON DIGESTION.

THE EFFECTS OF LONG-PROTRACTED ABSTINENCE.

(NOTE I. See p. 62.)

THE effects of protracted abstinence on the human subject are well illustrated by the following facts:—During the famine which desolated certain parts of France in the year 1817, especially during the months of April, May, and June, when the miserable inhabitants had exhaused their stock of provisions, and when they were reduced to live on herbaceous vegetables only, as wild sorrel, nettles, patience,

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tic secretions. *d.* Over the secretions and functions of the urinary organs.—D. Their influence on the mass of blood circulating through the heart and blood-vessels. *a.* As regards the changes induced in this fluid during respiration. *b.* As respects the phenomena which it displays after having been drawn from an artery and vein in the general circulation, during various states of the system. *c.* The power of these organs in the production of animal heat.—2. The functions of these organs, viewed in connexion with the muscular fibres of involuntary motion.—3. The probability of their being the chief source of irritability contended for, and the varying characters of this principle explained, as it is displayed in the different muscular textures and capillary vessels.—4. The influence of the brain and spinal chord upon the operations of the organs under consideration, viewed. *a.* In respect to the manner and extent in which the former affect the contractions of the heart. *b.* As they (the voluntary nerves) may affect the capillary circulation of a part, and proofs of their limited influence over the vascular ramifications. *c.* With regard to the small extent of power which the brain and spinal chord can exert over the functions of digestion, unless through the medium of the ganglions.—5. A general view of the phenomena to which the ganglial ramifications give rise, when reinforced by the nerves properly so called.—6. The manifestations to which they give rise in the inferior classes of the animal creation.—7. The functions of the ganglions, as they regard the generative process. *a.* In the male. *b.* In the female.—8. Their influence in the formation and nutrition of the textures, and in the progress and decay of the animal, considered.—9. The effects produced on different animals by the application of certain substances to the expansion of these organs.—10. The consideration, that the manifestations essentially vital are the result of these organs, entertained, argued for, and explained, from the inferences deduced from the foregoing sections.—11. A general view of the doctrines contained in this part of the treatise."—*Lond. Med. Repos. for May* 1822.

* Violent blows or contusions on the epigastric region, when they do not immediately destroy the individual subject to them, depress in a very remarkable manner the vital energies of the system. The animal heat is uncommonly diminished, the surface is cold and pale, the pulse slow and scarcely perceptible, and the breathing feeble and very slow. An analogous effect, in some respects, is produced by concussion of the semilunar ganglion, as that which follows concussion of the brain: in the former, the vital or organic actions are either exhausted or destroyed; in the latter, the animal or voluntary operations only are suspended.

succory, thistles, the tops of beans, the sprigs of young trees, &c., M. Gaspard* observed that a general serous diathesis prevailed, or universal anasarca of the cellular membrane, without ascites, jaundice, or any organic lesion of the liver, or of any of the abdominal viscera. Many women experienced an interruption of the catamenia; and a reference to the register of births subsequently in the communes which suffered from the famine, shewed that the number of conceptions was less by more than one-half during the three calamitous months of that year than during the same months of the preceding and following years.

During these months many assuaged their hunger by eating snails, of which an incredible number was destroyed; but those who largely partook of them experienced a state of stupor, analogous to that produced by belladonna.

A tradesman, impelled by a succession of misfortunes, retired to a sequestered spot in a forest in Germany, and there resolved to starve himself to death. He put his determination in force on the 15th of September, 1818; and was found eighteen days after still living, although speechless, insensible, and reduced to the last stage of debility. A small quantity of liquid was given him, after which he expired. By his side was found a pocket-book and pencil, the former containing a daily journal of his state and sufferings up to the 29th of September, four days before his death. He had constructed a little hut of bushes and leaves. On the 17th of September (the second day) he complained of suffering from cold; on the 18th he mentioned having suffered from intolerable thirst, to appease which he licked the dew from the surrounding vegetables. On the 20th he found a small coin, and with difficulty reached an inn, where he purchased a bottle of beer; the beer failed to quench his thirst, and his strength was so reduced, that he took three hours to accomplish the distance, which was about two miles. On the 22d he discovered a spring of water, but though tormented with thirst, the agony which the cold water produced on his stomach excited vomiting and convulsions. The 25th made ten days since he had taken any food but beer and a little water. During that time he had not slept at all. On the 26th he complained of his feet being dead, and of being distracted by thirst; he was too weak to crawl to the spring, and yet dreadfully susceptible of suffering. The 29th of September was the last day on which he made a memorandum. No dissection of his body was made.†

A criminal, called Viterbi, determined, on the 2d of December, to starve himself to death, in the prison of Bastia, where he was confined. During the three first days of the attempt, he felt himself progressively tormented by hunger. He manifested no debility during these three days, nor any irregular muscular movement; his ideas continued sound, and he wrote with his usual facility. From the 5th to the 6th of December the much more grievous suffering of thirst succeeded insensibly to hunger. Thirst became so acute on the 6th, that without ever deviating from his resolution, he began to moisten his lips and mouth occasionally, and to gargle with a few drops of water, to relieve the burning pain in his throat; but he let nothing pass the organs of deglutition, being desirous not to assuage the most insupportable cravings, but to mitigate a pain which might have shaken his resolution. On the 6th his physical powers were a little weakened; his voice was, nevertheless, still sonorous, pulsation regular, and a natural heat equally extended over his whole frame. From the 3d to the 6th he had continued to write; at night several hours of tranquil sleep seemed to suspend the progress of his sufferings: no change was remarkable in his mental faculties, and he complained of no local pain.

Until the 10th, the thirst had become more and more insupportable: Viterbi, however, merely continued to gargle, without once swallowing a single drop of water; but in the course of the 10th, overcome by excess of pain, he seized the jug of water which was near him, and drank immoderately. During the last three days, debility had made sensible progress, his voice became feeble, pulsation had declined, and the extremities were cold. He, however, continued to write; and sleep each night afforded him a few hours ease.

From the 10th to the 12th the symptoms made a slight progress. His constancy never yielded an instant: he dictated his journal, and afterwards approved and signed what had been written agreeable to his dictation. During the night of the 12th the symptoms assumed a more decided character; debility was extreme, pulsation scarcely sensible, his voice extraordinarily feeble; the cold had extended itself all over his body, and the pangs of thirst were more acute than ever. On the 13th, the unhappy man, thinking himself at the point of death, again seized the jug of water and drank twice, after which the cold become more severe; and, congratulating himself at the approach of death, he stretched himself on the bed, and said to the gendarmes who were guarding him, "Look how well I have laid myself out." At the expiration of a quarter of an hour, he asked for some brandy: the keeper not having any, he called for some wine, of which he took four spoonsful. When he had swallowed these, the cold suddenly ceased, heat returned, and he enjoyed a sleep of four hours.

On awaking (on the morning of the 13th), and finding his powers restored, he fell into a rage with the keeper. During the two following days, he resisted his inclination to drink, but continued to gargle occasionally with water. During the nights he suffered a little from exhaustion, but in the morning found himself rather relieved. It was then he composed some stanzas. On the 16th, in the morning, his powers were nearly annihilated, pulsation could hardly be felt, and his voice was almost wholly inaudible; his body was benumbed with cold, and it was thought that he was upon the point of expiring. At 10 o'clock he began to feel better, pulsation was more sensible, his voice strengthened, and heat again extended over his frame; and in this state he continued during the whole of the 17th. From that day until the 20th he only became more inexorable in his resolution to die.

During the 19th, the pangs of hunger and

* *Journ. de Physiol. Exper.* No. III.

† Journal der Practisch: Heilkunde, &c. C. W. Hufeland, Marz, 1819

thirst appeared more grievous than ever, so insufferable indeed were they, that, for the first time, Viterbi let a few tears escape him; but his invincible mind instantly spurned this human tribute. For a moment he seemed to have resumed his wonted energy, and said, in the presence of his guards, "I will persist; my mind shall be stronger than my body; my strength of mind does not vary, that of my body daily becomes more weak." A little after this energetic expression, which shewed the powerful influence of his moral faculties over his physical necessities, an icy coldness again assailed his body, the shiverings were frequent and dreadful, and his loins, in particular, were seized with a stone coldness, which extended itself down his thighs.

During the 19th, a slight pain at intervals affected his heart, and, for the first time, he felt a ringing sensation in his ears. At noon on this day, his head became heavy; his sight, however, was perfect, and he conversed almost as usual, making some signs with his hands. On the 20th, he declared to the gaoler and physicians, that he would not again moisten his mouth; and feeling the approach of death, he stretched himself on the bed, and said, "I am prepared to leave this world." Death did not this time betray his hopes: on the 21st he was no more. Until the day of his death, this man regularly kept his journal. The delivery of it to his friends was refused.*

OF DIGESTION.

(NOTE K. See p. 73, *et seq.*)

I. *Of digestion in the stomach.* — M. Lallemand has drawn the following inferences from his observations and experiments on digestion :—

"1. That, if it be true that alimentary substances the most perfectly animalised contain the most nutritive matter, it does not thence follow that they are the most rapidly digested.

"2. That, on the contrary, the process of digestion is more long and laborious, as, in a given volume, the aliment contains more nutritive matter, and *vice versâ*.

"3. That the aliments do not escape from the stomach in the order which they are introduced, for it is not those which are first altered by digestion that pass the first: it is those, on the contrary, which, containing least alimentary matter, are most refractory to the digestive powers."

Agreeably to the inferences stated, (in note H. of the App. pp. 12, 13,) we consider, that whatever may be the order in which the ingesta pass the pylorus into the small intestines, the digestive process in the stomach, and, indeed, throughout the alimentary canal, is more immediately the result of the vital influence with which the stomach and intestines are endowed, than of the solvent properties of the gastric juice. We, however, by no means, would be understood to deny that these properties are requisite to the process; we only contend that they are subordinate to the manifestation of vitality exerted by the stomach, and that the vital influence of this viscus is chiefly concerned in its performance. The digestive process, whether that part of it which is performed in the stomach, or that which is accomplished by the small intestines, appears to be essentially a vital process, whether we view it in man or in any of the lower animals. Every theory, therefore, which excludes its immediate operation, must be defective. Conformably to this view, it must be supposed to vary in activity,—as, indeed, we actually find that it does,—according to the state of the vital influence with which the organs concerned in its accomplishment are originally endowed, and according to the state and distribution of this influence throughout the organs and textures at the time when this process is going forward. We do not deny that the influence which we impute to the stomach is one which is not intimately connected with the gastric juices; on the contrary, we believe that they are the medium through which it acts, —in short, that, owing to the abundant supply of nerves which this viscus receives, chiefly from the ganglionic system, it possesses a considerable share of the vital influence of the body; that this influence is chiefly exerted in giving rise to its organic motions, and in producing its specific secretions; and that, from the circumstance of so large a proportion of its ganglial nerves being distributed on its arteries, the juices which they secrete or exhale are imbued with an emanation or some certain manifestation of this influence, which is the principal agent in the digestive process. Hence the relation between the states of this influence and the quantity and quality of the gastric juices, must be very intimate; and it seems to be owing to this intimacy that the primary agent has been hitherto overlooked in the more evident and grosser materials with which it is allied, and by means of which it operates. The varying conditions of the function of digestion in health and in disease, and the close connexion between it and every manifestation of the body, eminently support this view of the subject; and, independently of the direct evidence furnished by the very interesting experiments of Drs. Wood and Sillar, of Liverpool, many collateral proofs may be adduced in its behalf.

II. *Of human rumination.* — The author has adverted to this subject in the text, (p. 75), in a very brief manner. As this affection is more frequent amongst individuals apparently enjoying their usual health than is generally supposed, and as many who habitually ruminate consider it to be only a step of the digestive process,—which is certainly the truth as far as respects themselves,—we shall enter more fully into the subject, as it has more than once fallen under our observation.

Under the usual circumstances, rumination commences from a quarter of an hour to an hour and a half after a meal. Immediately upon the commencement of this act, a slight sensation of fulness may be felt at the cardia, when the attention is particularly directed to it, that leads to a deeper inspiration than usual. So soon as the act of inspiration is completed, and while the muscles of the glottis remain fixed, a bolus of the unchanged aliment rises rapidly from the stomach with the first effort at respiration, at the moment when the diaphragm has just relaxed and the re-action of the abdominal muscles commenced. But expiration does not take place until the alimentary ball has passed completely into the mouth, as the

* From the Corsican Gazette.

glottis remains closed until then: upon this having taken place, expiration is immediately effected; and so rapidly does expiration succeed to the regurgitation of the alimentary bolus, that the latter, (unless when the attention is closely applied to the subject), appears as part of the expiratory act.

The ruminating process is never accompanied at any time with the smallest degree of nausea, nor any pain or disagreeable sensation. The returned alimentary bolus is attended with no unpleasant flavour, is in no degree acidulous, is equally agreeable, and is masticated with additional pleasure, and with much greater deliberation, than when first taken.

The whole of the aliments taken at any one meal is not returned in order to undergo this process, but chiefly the part that has been insufficiently masticated.

The more fluid portions are not always returned, unless along with the more solid or imperfectly masticated parts. When, however, the stomach is distended by a large meal, the fluid contents are frequently returned, and subjected to this process.

This affection may be considered as being passively under the control of the will; and although it sometimes takes place when the individual is nearly unconscious of the process, yet it never occurs when the mind is incapable of being acted on by external impressions received by the senses. Thus, if at any time, from previous fatigue, and the concentration of the organic nervous energy towards the digestive organs, sleep be induced immediately after a full meal, this affection does not take place; but flatulence, acrid eructations, &c. usually supervene, and continue for some time, in consequence of the vital energy and gastric juices being insufficient to the production of the requisite changes on the ingesta retained in a state of imperfect division.

With respect to the nature of human rumination, it appears evident that it only takes place when the vital energy of the assimilating organs is greatly diminished; consequently, when the activity of the stomach, both as it relates to its muscular action and secreting functions, is equally lessened: this is apparent from the circumstances, that aliments, if they be taken even in very moderate quantity, are not properly digested by ruminating individuals when they are retained without having been resubmitted to mastication. Connected also with debility of the stomach, an increase of its sensibility, which it derives from the distribution of the eighth pair of nerves, seems to be present. Both these states of this organ render it more necessary that the ingesta should undergo a perfect mastication and thorough admixture of the salivary juices, in order to suit it to the weakened functions of the stomach.

Under the circumstances of deficient vital energy of the stomach, of increased sensibility, and diminished secretion, a small portion only of food can be digested; yet it is, nevertheless, generally taken in considerable quantity by ruminating individuals. In this case, that portion of it most favourable to the admixture having combined with the gastric juices, and being, by the natural action of the stomach, conveyed to the pylorus, the undigested portions, and those which have been imperfectly masticated, must either remain at the cardiac extremity, or be propelled there by the usual action of the viscus, where they excite its organic sensibility, and, in consequence of intimate nervous connexion, the co-operation of the muscles of respiration, especially of the diaphragm and abdominal muscles, and thus give rise to the ruminating process.

In its performance, the organic contractility of the stomach can do no more than, by an elective process (soon to be explained), place the aliments about to be returned in a situation, in respect to the cardia, favourable to the excitation of the organic sensibility of this organ, and to its ready regurgitation and propulsion along the œsophagus. As soon as the demand is made upon the sensibility, by the situation of the alimentary bolus, the par vagal class of nerves is excited to action, and a full respiration is effected, as has been described. The introduction of the bolus into the cardiac extremity of the œsophagus may be considered as effected by the ordinary contractility of the stomach, perhaps sympathetically heightened at the moment by the reaction of the abdominal muscles; while, at the same time, the diaphragm has just undergone relaxation, in which the cardia may, from intimate nervous communication, also participate, and thus facilitate the ascent of the alimentary ball in the œsophagus, which immediately contracts behind it, from the irritation produced by its passage, and the bolus is thus conveyed to the mouth.

That relaxation of both the diaphragm and cardiac extremity of the œsophagus actually exists at the moment, although the glottis still remains closed, appears confirmed, both by the period of the respiratory act at which this process is produced, and by the circumstance that, when any restraint is exercised over this affection, it is principally by means of exciting the diaphragm to a frequent and continued action, when the premonitory sensation is felt at the cardia.

The influence of the will appears to be requisite, since the process is interrupted during sleep. But this influence is only passively engaged in the production of the ruminating act, by bringing about the co-operation of the respiratory organs.

The elective process exercised by the stomach in this affection is similar to that which it exerts in periods of health, which may be considered as relative to the degree of digestive energy, and to the comparative states of comminution and insalivation in which the various ingesta may enter the stomach.

During the process of digestion, contraction takes place irregularly and in various situations in this organ, according as different portions of the longitudinal or circular fibres may act: this operates in producing a degree of arrangement in the aliments; and the gastric juices combine with the more soluble portion of the food, especially that situated towards the mucous surface of this organ, and form the chyme, which is conveyed by the varying organic contractility of the muscular coat towards the pylorus; while a successive and concentric stratum of aliment comes in contact with this surface, and, if in a permeable state from its previous comminution and admixture with the salivary juices, is soon penetrated by the gastric secretions; and even the central mass not unfrequently is obliged to yield its more fluid parts to the exterior layer, when there is a deficiency of fluids in the alimentary matters. Hence the not unusual ne-

cessity for drink that takes place as digestion proceeds. In the course of this process, as it is the result of the healthy functions of the organ, the chyme in contact with its mucous surface is conveyed in a direction from the cardia to the pylorus. But, if the propulsion of the digested contents towards this extremity of the organ goes on faster than they can pass through into the duodenum, the accumulation of chyme that consequently takes place in that direction tends to throw back the less soluble portions towards the cardia; where, according to the state of the organ, they may produce cardialgia, acrid eructations, or even rumination.

In the debilitated state of the stomach, and consequent deficiency of the secretions, digestion can be perfectly performed only when the aliments are presented to it in small quantity, and in a favourable state of complete comminution and intermixture with the salivary juices. If, however, in this condition of the organ, the food is conveyed rapidly into it, possessed of neither of these requisites, so as to produce sudden distension, a reaction of this viscus upon its contents takes place; and as the imperfectly masticated food constitutes the greater portion of the ingesta, there is abundance present to be returned into the cardia and to be regurgitated, while there is a deficiency of aliment in a fit state to combine with, or to be operated upon by, the gastric juices; but this latter, when converted into chyme, is rapidly conveyed to the pyloric extremity of the organ, by the reaction of the muscular coat, arising from undue distension and the stimulus of solid contents. Thus, a double effect is produced by the healthy organic contractility of this viscus, when in a weakened state and yielding a diminished quantity of the usual fluids, which state, indeed, may be considered as constituting this peculiar affection, — namely, the part of the aliment which is dissolved by the gastric juices is conveyed towards the pylorus, whilst the tonic action of the stomach, tending to diminish its capacity, pushes the less comminuted and indigestible portions of food into the unresisting cardia, whence they are returned, as we have described, in order to undergo a second comminution and intermixture with the salivary juices; after which they are in a fit state to be conveyed to their destination along the mucous surfaces, with the juices of which they combine, and thus permit a central portion of the mass to return and undergo a similar process.

III. *Of the influence of the pneumo-gastric nerves in digestion.* See p. 84.— The experiments of Dr. Philip, although they by no means warrant the inferences which he deduced from them, shew that the eighth pair of nerves conveys the influence of the cerebro-spinal system to the stomach, and reinforces and stimulates the vital energy bestowed on it by the ganglial system. This conclusion is farther supported by the experiments lately performed at Paris by MM. Breschet, Edwards, and Vavasseur. The inferences which these physiologists have drawn from their experiments are,

1st. Simple section of the two pneumo-gastric nerves in the region of the neck, without loss of substance, and without separating the cut extremities, does not prevent digestion from taking place, but merely retards it in an evident manner.

2dly. Section of these nerves with loss of substance diminishes considerably, and much more than simple section, the digestive action of the stomach, but it does not appear to abolish it completely.

3dly. Section or destruction of a part of the spinal marrow, or ablation of a portion of the brain, acts in the same manner on the changes which the food undergoes in the stomach.

4thly. Narcotics, administered so as to produce coma, equally diminish the energy of the digestive powers.

5thly. It results, consequently, that every thing which diminishes the amount of nervous influence transmitted to the stomach, weakens the digestive action.

6thly and finally. When digestion is almost completely suspended by the section, with loss of substance, of the pneumo-gastric nerves, the digestive action of the stomach may be re-established, and the food contained therein be converted into chyle, by means of the galvanic influence, with almost as much rapidity, and as perfectly, at least in appearance, as under ordinary circumstances.*

When the connexions of the different orders of nerves which supply the stomach are considered, and the intimate relation consequently subsisting between this organ and the centres to which these nerves respectively belong, it cannot for a moment be doubted that the interruption of the channel through which this connexion takes place should be followed by a deranged state of the functions depending thereupon. Allowing that the stomach derives its chief and its more vital influence from the ganglial system, and an additional and a modified influence from the cerebro-spinal system, the latter exciting or otherwise influencing the former,—and granting that respiration is requisite to the energy of both,—it surely cannot be for a moment doubted, that an interruption either of the one or the other should occasion, owing both to the defect of a requisite influence and to the injury done to the system generally by the experiment, a very considerable derangement of the functions of this organ. We perceive that slighter causes, such as those mentioned at p. 84 of the text, will produce a much greater disorder of the actions of the stomach than the formidable operation of division of the eighth pair of nerves—formidable not only as respects its effects upon digestion, but as regards its influence on the function of respiration and upon the body generally. Can it therefore be a matter of surprise, that destruction of, or interruption to, a wonted and requisite influence, should be followed by marked effects upon the organ which such influence is destined to actuate? Because the influence conveyed by the nerves from the cerebro-spinal system affects the functions of the stomach, or an interruption to it disorders them, can it therefore be logically concluded that this viscus derives its functions from that source, and that none of them acknowledges any other origin? Because these particular nerves are ready conductors of galvanism, and because galvanism excites the natural actions of the digestive organs, ought it therefore to be concluded, that the natural office of these nerves is to convey and distribute this agent, or that the vital influence with which these organs are endowed, is identically the

* *Archives Générales de Médecine, Aout*, 1823.

same as it? We think that no one can be justified in answering these questions in the affirmative, by the evidence which these experiments afford.

From a careful consideration of the phenomena which these experiments furnished, and from the few experiments which we have made with this active agent, we conclude, 1st. That the functions of the stomach depend chiefly upon the supply of ganglial nerves, which its vessels, muscular fibres, and secreting surface, receive. 2. That the pneumo-gastric nerves convey the influence of the cerebro-spinal system to this organ, which influence reinforces that which it receives from the ganglial system, or proves a stimulus to it. 3rd. That this latter influence is more requisite to the perfect performance of the functions of the stomach the older the animal is, and the higher we rise in our observations amongst the more perfect animals. 4th. That when this influence is interrupted, in a more or less complete manner, in its course to the stomach, its place may be, in some measure, supplied by galvanism, which seems to excite the proper or vital influence which the organ receives from the ganglial system. 5th. That we have no proof of galvanism acting otherwise in the process than as a stimulus to properties already possessed by the organ on which it acts, and that it acts in those experiments through a medium to which the organ is habituated, and in a great measure dependent for a natural excitant. 6th. That although galvanism excites the functions of the stomach for a time, we have no evidence of its continued power in promoting them during a protracted interruption of either the one species of nervous influence or the other; it even appears probable that the continued operation of this agent, although, like other powerful stimuli, it at first actively excites the natural functions of the part on which it acts, would, nevertheless, exhaust them, more especially if they were not uninterruptedly supplied from their natural sources. 7th. That as we have no comparative trials of the effects of other powerful stimuli under similar circumstances to those in which galvanism has been employed, conclusive inferences cannot be drawn respecting the extent of influence of that agent; at least none that can oppugn the above positions; they may, and very probably they will, confirm them, and shew that the activity of galvanism in exciting the animal operations merely results from the properties of this agent enabling it to act, through channels which convey a natural and a requisite influence, in a more energetic manner than other excitants which we can employ in our experiments. Reasoning, indeed, from what we already know of the properties of galvanism, and from its operations upon inorganised matter, we should be led to expect more energetic effects from it upon the animal system than from any other agent which we have under our control.

OF VOMITING.

(NOTE L. See pp. 85—87.)

Whilst we attribute the digestive process chiefly to the vital influence proceeding from the ganglial system, we do not overlook the fact that that part of this system supplying the stomach is acted upon to a certain extent, through the medium of nerves communicating with, and of others given off from, the cerebro-spinal system, which may reasonably be supposed to perform the functions belonging to their respective sources.

It is owing to this provision, when the stomach is irritated, and when its organic contractility is inordinately excited, that its sensibility is also roused, — the influence is propagated to the sensorium, and contraction of the abdominal and respiratory muscles is also produced, — which contraction co-operates with that of the stomach itself in giving rise to vomiting.

Magendie has inferred from his experiments, that it is only the contraction of the abdominal muscles and diaphragm which produces vomiting, and that the stomach has no share in the act. This physiologist, on this, as on other occasions, has not taken into account the various sources of error to which experiments on living animals are liable. He has not sufficiently considered or calculated upon the unnatural positions in which such experiments place the animals experimented upon, and thus derange their natural operations. Stricter and more comprehensive views of the subject shew, that whilst former physiologists have erred in attributing the act of vomiting too exclusively to a sudden contraction of the stomach, Magendie and his disciples have been equally to blame in adopting too implicitly the more tangible phenomena of some inconclusive experiments.

The steps in this process appear to be the following:—An irritating cause rouses the organic sensibility of the stomach, and gives rise to a considerable contraction of its muscular coats. This exalted state of its organic sensibility and contractility excites, in consequence of the intimate nervous communication between the stomach on the one hand, and the diaphragm and abdominal muscles on the other,* the action of the latter, which, from vicinity of situation, perform so important a share in the act. Hence it follows, that neither the contraction of the stomach alone, nor that of the muscles only, can be sufficient to give rise to the act of vomiting. It would seem, that so intimately connected are inordinate irritations of the stomach with the action of the diaphragm and abdominal muscles, owing to the anatomical relations of the ganglial system with the eighth pair of nerves and with those of the spinal chord, that the one can never take place, under the ordinary state of the system, without being followed by the other, and giving rise to the act under consideration. The nausea which precedes vomiting is merely the sensible impression made by the irritating cause on the nerves of the stomach, which impression, if sufficiently exalted, terminates in the act in question. When this step of the process is about to take place, the diaphragm is the first to contract in a spasmodic manner; indeed, the irritation of the stomach having excited the diaphragm, the former is struck by the latter against the abdominal muscles, and at the instant when the diaphragm relaxes, the abdominal muscles re-act and impel the stomach against the relaxed and ascending diaphragm, which, in consequence of this state,

* Through the medium of the eighth pair of nerves, and of the branches of the ganglial system which join the spinal nerves.

readily allows the contents of this viscus to be impelled by the concussion of the abdominal muscles, through the cardia into the œsophagus. At the moment when the abdominal muscles act, the glottis is closed, and thus portions of the ejected contents of the stomach are prevented from falling into the larynx. That the glottis is closed at the commencement of the act of ejection, seems undeniable; but it is frequently relaxed towards the close of the act, so that expiration takes place very fully; and thus the matters which are the last ejected from the stomach are frequently accompanied with substances from the bronchia, and hence the difficulty often of stating whether certain matters excreted by vomiting have actually come from the stomach or lungs. That the diaphragm is the first to contract and that it is the first to relax, are shewn by attending to the steps of the process, and by the fact, that the stomach could not empty itself through the cardia if the diaphragm were to continue in a state of contraction. It will, therefore, appear, that the action of the stomach is at its acmé when the abdominal muscles re-act and consummate the process; and that, whilst the diaphragm commences the operation, the abdominal muscles are chiefly efficient in perfecting it. It must be kept in recollection, that both do not contract at the same time. The violent action of the abdominal muscles impels the stomach, and, indeed, the superior viscera of the abdomen, so forcibly upon the relaxed diaphragm, and encroaches so much upon the cavity of the thorax, that the lungs are at the time considerably pressed upon, and this pressure is farther increased by the ascent of the contents of the stomach through the œsophagus. Hence it is that vomiting always promotes the discharge of secretions which have accumulated in the bronchia.

OF THE INTIMATE STRUCTURE AND FUNCTIONS OF THE LIVER.

(NOTE M. See p. 88.)

The very minute researches of Dr. J. M. Mappes, of Frankfort on the Maine, on the intimate structure of the liver, throw considerable light on the functions and pathology of this important viscus.* "If water be slowly injected into the vena portæ," this physiologist remarks, "it will force blood and some bile from the hepatic veins; and ultimately it will itself pass out of those vessels. If the liver be now examined, either by dissecting off the peritonæum, or cutting or tearing the liver, two structures will be observed: the one *granulated*, forming convolutions, now resembling those of the intestines, and now branching in other forms, flattened and yet rounded, dense and of a yellow colour, and about a quarter of a line in diameter; the other a *cellulo-vascular structure*, of a brown colour, which fills up the rounded spaces or oblong fissures, of from a quarter to half a line in diameter, which separate the convolutions from each other. These structures are well shewn, if water in which cinnabar has been diffused be thrown into the hepatic veins; for the cinnabar is precipitated on the sides of the vessel, and the water passes by the vena portæ. Between the convolutions are found triangular and somewhat broken openings, which communicate with each other by little chinks. Some of these contain twigs of the hepatic vein; in the others, and especially where the chinks are traced to a great depth, and where the vessels form larger trunks, three vessels are seen together,—a large one belonging to the hepatic vein, and two others of a smaller diameter, belonging to the artery and the hepatic duct.

"If the hepatic vein be excepted, the other vessels form branches like a tree, as in the rest of the body. The artery, however, gives the most branches; apparently because they surround, like a capillary net-work, the parietes of the vena portæ, to which purpose they seem to be particularly destined; although some branches penetrate to the surface of the liver, and are distributed on the peritonæum, but without forming a net-work, as in the former case. The ramifications of the hepatic artery and the hepatic duct are always strictly united together; and in accompanying the larger branches of the vena portæ, they do not intertwine at the two opposite sides of the latter vessel.

"The large branches of the hepatic duct divide at an acute angle; but the ramifications divide at right, or even obtuse angles. It is these latter short and loose twigs which form the parallel ranges of holes, which are seen by cutting the liver in the direction of a branch. These holes are the orifices of vessels, as is seen by injection or by dissecting the twigs; they cannot, therefore, be confounded with the little dimples which are seen on the internal parietes of the largest hepatic trunks. All the ramifications of the hepatic trunk, indeed, when cut, present a gaping firm opening, like an artery; whilst the cut orifices of the vena portæ which accompany them are always in a collapsed state.

"The duct ramifies something like the vein. The short and thick trunks divide into branches, and form a crowd of smaller and looser twigs, which embrace the grains of the granular substance above described, but apparently without penetrating the substance of them. Hence, these grains are somewhat separated from each other, and they in some degree compress the cellulo-vascular substance, without, however, giving any of their colour to the latter, which is only traversed by some injected vessels.

"The parietes of the artery, the vena portæ, and the hepatic duct, do not adhere to the substance of the liver; but are separated from it, as may be seen by the microscope, partly by an uniform gelatinous matter, and partly by an extension of the cellular membrane, which composes the capsule of Glisson. The hepatic vein, on the contrary, adheres intimately to the granulated substance; it also follows, without variation, the latter in its distribution, and the smallest branches penetrate between its granulations. These facts prove the intimate relation which exists between the vein and the granular substance; whilst the artery and vena portæ ramify together in the cellulo-vascular substance, and on the surface of the principal circumvolutions of the granulated substance; and the hepatic duct, the twigs of which are averted from each other, seems to hold a relation with both orders of vessels.

"If a single hepatic vessel be injected, the injection will only pass to the part to which that

* *Journal Complémentaire du Dictionnaire des Sciences Médicales*, No XLVII. Mai 1822.

branch is distributed: on the contrary, water passes rapidly and easily from the vena portæ to the hepatic vein, and *vice versâ*. Wax, however, rarely passes, and the hepatic duct is never filled either from the vena portæ or hepatic vein."

From these facts, M. Mappes is led to consider the granular substance to be the secreting part of the liver, around which the vessels are grouped as the conducting and preparatory apparatus. The more intimate connexion which it holds with the radicles of the hepatic vein, has induced him to presume that the bile is more probably separated by it from the blood which had actually arrived within these radicles, than from that which circulates in the extreme ramifications of the vena portæ. This particular substance appears also to M. M. to form the basis of all the glands, and to be of a peculiar nature, modified according to the functions which nature has imposed on it. He further supposes, that in all glandular structures there exists an intermediate substance between the extreme ramifications of both orders of vessels, which holds a more intimate relation with the changes induced in the blood than the other parts through which it circulates. This substance he conceives to be of a mucous character, and to form the basis of the granular part of the liver and other glands in which the vessels terminate and commence, and which, he thinks, is entirely appropriated to the particular function and destination which the gland is intended to fulfil. In proof of this he quotes Dœllinger, who has adopted a similar opinion. M. Mappes, in an analysis which he offers of Eysenhardt's investigations respecting the anatomy of the kidney, concludes that the intimate structure of this organ and the liver is in many respects similar.

Although it is generally agreed amongst physiologists that the secretion of the bile takes place in the granular structure of this viscus, it is by no means so generally allowed that the secretion is furnished by the blood of the vena portæ. Bichât contended that the bile is secreted from the hepatic artery, and adduced numerous analogies in support of the opinion. More recently, M. Magendie has considered it to be formed, at the same time, from the blood of both the portal and arterial systems. The investigations of M. Mappes may, therefore, be regarded as having set at rest the long-agitated question respecting the vessels secreting the bile, since they shew that the terminations of both the vena portæ and hepatic artery meet in the granular structure of the liver, and that they combine to furnish materials for this secretion, which is produced by the granulæ from which the radicles of the hepatic ducts arise.

Assimilating and secreting functions of the liver.—It seems to us most probable, reasoning from the facts ascertained respecting absorption, that the blood which circulates in the vena portæ, being that which is possessed of the venous character in the highest degree, and which, moreover, has a considerable portion of new materials — the products of digestion and absorption—poured into it before it reaches the liver, — undergoes there those changes which are necessary to a perfect assimilation of these materials,* and to the future offices which the blood itself has to perform in the animal economy; and that in the course of, or in addition to these changes, the blood of the vena portæ has certain of its elements eliminated from it, the elimination of which is requisite not only to the accomplishment of these changes, but also to the production of a secretion which performs certain offices in the process of digestion. This view of the subject is supported by the following facts, — 1st, that those elements of which the bile is composed abound most in the blood of the vena portæ, and that if they were to remain in the blood circulating throughout the body, consequences subversive of its healthy existence would rapidly supervene; 2d, that the portal ramifications are plentifully supplied with the ganglial nerves, which we have shewn to be the source whence the blood-vessels derive their vitality and functions, and the origin of those changes which the fluid circulating in them experiences;— and 3d, that the divisions themselves of the vena portæ receive a much greater supply of arterial capillaries from the arteria hepatica than is observed with respect to any other vein in the body.

From anatomical investigation, therefore, from numerous experiments bearing indirectly on the subject, and from pathological observation, we infer that the blood which is returned from the digestive tube, from the spleen, &c. (having been shewn to contain a considerable portion of absorbed materials, some of them of a more or less heterogeneous description, others of them more or less animalised; and, moreover, that certain of the elements or constituents of the blood, requiring to be eliminated from the system, are there in an increased and hurtful quantity if they be allowed to remain in it,) undergoes in the liver most important changes; that these changes are of two kinds, the one referring to the assimilation of the less animalised materials which the blood may contain, the other to the elimination of the heterogeneous, hurtful, or effete elements which may circulate in it; that these changes are produced through the medium of the vessels and granular structure of the liver, by the vital influence with which both are endowed from the ganglial nerves supplying them; that these changes are perfect or defective in proportion as that influence is perfect or defective, provided that the structure of the parts, the instruments of this influence, be not deranged; and that as the vital functions of the organ, depending upon the sources pointed out, may vary very greatly, and as the structure of one or more of the parts constituting the organ may consequently become deranged, the operations of the liver may be thus disordered in a simple or more or less complex manner.†

* See the Note on Absorption from the Intestinal Canal.

† It seems most probable, that recently secreted bile, during the healthy function of the liver, is a bland, albuminous, and alkaline fluid, its larger portion recrementitious, and combining with the nutritious portion of the chyme to form the chyle. If, then, the bile is secreted in a state of comparative mildness and fluidity during the healthy state of the liver, how comes it to change its characters in the gall-bladder and in the liver itself? 1st. With respect to its change in the gall-bladder: this may be explained by inferring that an absorption of its more

Of the uses of the bile.—Various opinions have been entertained by physiologists respecting the purposes of the bile. "Some have supposed that the secretion of the bile is merely excrementitious; others that the bile is intended to stimulate the intestine, and to produce a ready evacuation of the fæces; and another opinion has been, that the bile is poured out into the duodenum that it may be blended with the chyme, and producing chemical changes in it, convert it into chyle. The situation of the liver, connected as it is in every instance with the upper part of the alimentary canal, is unfavourable to the first of these hypotheses; but the last is rendered very probable by the circumstance of chylification taking place just at the part where the bile flows into the bowel."

In order to arrive at some satisfactory conclusion on these points, Mr. Brodie applied a ligature round the choledoch duct of an animal, so as completely to prevent the bile entering the intestine, and then noted the effects produced on the digestion of the food which the animal had swallowed, either immediately before or immediately after the operation. The experiment was repeated several times, and the results were uniform. Before he describes these results, he remarks, that "the application of a ligature round the choledoch duct is easily accomplished, and with very little suffering to the animal; so that any derangement which follows, in the functions of the viscera, cannot reasonably be attributed to the mere operation. The division of the stomachic ropes, or terminations of the eighth pair of nerves on the cardia of the stomach, and the ligature of the whole extremity of the pancreas, are operations of much greater difficulty; yet it has been ascertained that neither of these at all interfere with the conversion of the food into chyme, or that of the chyme into chyle."

"When an animal," Mr. Brodie proceeds to state, "swallows solid food, the first change which it undergoes is that of solution in the stomach. In this state of solution it is denominated *chyme*. The appearance of the chyme varies according to the nature of the food. For example, in the stomach of a cat, the lean or muscular part of animal food is converted into a brown fluid, of the consistence of thin cream; while milk is first separated into its two constituent parts of coagulum and whey, the former of which is afterwards redissolved, and the whole converted into a fluid substance, with very minute portions of coagulum floating in it. Under ordinary circumstances, the chyme, as soon as it has entered the duodenum, assumes the character of *chyle*. The latter is seen mixed with excrementitious matter in the intestine, and in its pure state ascending the lacteal vessels. Nothing like chyle is ever found in the stomach; and Dr. Prout, whose attention has been much directed to the chemical examination of these fluids, has ascertained that albumen, which is the principal component part of chyle, is never to be discovered higher than the pylorus. Now, in my experiments, which were made chiefly on young cats, where a ligature had been applied so as to obstruct the choledoch duct, the first of these processes, namely, the production of chyme in the stomach, took place as usual; but the second, namely, the conversion of the chyme into chyle, was invariably and completely interrupted. Not the smallest

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fluid parts takes place during its remora in this receptacle, and that some change supervenes in its more active constituents, in consequence of which it gradually becomes possessed of the properties which it evinces under such circumstances. 2dly. As to the possession of these properties whilst yet in the liver: this circumstance can only be explained by the condition of the hepatic circulation and of the vital operations of the organ, either previously to, or co-existent with, this particular state of its secretion.

In cases of torpor of the liver and languid circulation in the vena portæ, and during congestion of the veins of this organ, the bile is very probably secreted of a morbid or vitiated character; or, although it may not be exactly such at the time of secretion, it may be more disposed to assume this quality during its passage along the ducts running in the substance of the liver. In circumstances of torpor of the liver, with languid circulation in the vena portæ, it can scarcely be supposed that the same condition does not extend itself to the branches of the hepatic duct. Indeed, it seems more correct to infer that this slow or impeded circulation is actually attended with congestion of bile in these branches; that during this congestion the more watery parts of this secretion are absorbed; and that the bile virtually undergoes, before it reaches the duodenum or gall-bladder, a similar change to that which it would have experienced during its remora in this receptacle. In cases of obstructed or impeded circulation, or even of congestion in the hepatic vein, a similar condition of the branches of the hepatic duct may be inferred, inasmuch as they both frequently depend upon the same causes, whether these causes belong to diminished energy of the organ, or mechanical obstructions of their respective trunks, or of parts influencing the functions of these vessels.

From these remarks it will appear that we consider the bile,—1st, to be secreted of a mild and bland description during the healthy condition of the liver, and especially in temperate or cold climates; 2d, that it may even possess these properties in a considerable degree as it flows into the duodenum; 3d, that it becomes more or less consistent, acrid, or stimulating, during its remora in the gall-bladder; 4th, that owing to the condition of the blood generally, or of that portion of it circulated by the vena portæ, the bile may be secreted of a more acrid or vitiated character, or it may more readily assume this character soon after its secretion, and whilst yet in the branches of the hepatic duct; 5th, that this character may often arise from torpor of the vital energy of the liver, or an obstructed or impeded circulation of the vena portæ, or of the hepatic vein; 6th, that it is often accompanied with congestion or obstruction of the hepatic ducts, similar changes taking place in the bile, during its congestion in the branches of the hepatic duct, to those supervening in the gall-bladder; and 7th, that this loaded and congested condition of the branches of the hepatic ducts often exists to a very great extent, as we have ascertained by frequent dissection, and that this condition may be termed congestion of bile in the liver

trace of chyle was perceptible either in the intestines or in the lacteals. The former contained a semi-fluid substance, resembling the chyme found in the stomach, with this difference, however, that it became of a thicker consistence in proportion as it was at a greater distance from the stomach; and that as it approached the termination of the ileum in the cæcum, the fluid part of it had altogether disappeared, and there remained only a solid substance, differing in appearance from ordinary fæces. The lacteals contained a transparent fluid, which I suppose to have consisted partly of lymph, and partly of the more fluid part of the chyme, which had become absorbed.

"I conceive that these experiments are sufficient to prove that the office of the bile is to change the nutritious part of the chyme into chyle, and to separate from it the excrementitious matter. An observation will here occur to the physiologist. If the bile be of so much importance in the animal economy, how is it that persons occasionally live for a considerable time, in whom the flow of bile into the duodenum is interrupted? On this point it may be remarked, 1st, That it seldom happens that the obstruction of the choledoch duct from disease is so complete as to prevent the passage of the bile altogether; and the circumstance of the evacuations being of a white colour, may prove the deficiency, but does not prove the total absence of bile. 2dly, That in the very few authenticated cases which have occurred of total obliteration of the choledoch duct in the human subject, there has always been, I believe, extreme emaciation, shewing that the function of nutrition was not properly performed. 3dly, That the fact of individuals having occasionally lived for a few weeks or months under these circumstances, only proves that nutrition may take place to some extent without chyle being formed. In my experiments I found that the more fluid parts of the chyme had been absorbed; and probably this would have been sufficient to maintain life during a limited period of time."*

Dr. Stearns, of New-York, is of opinion that the gall-bladder is not passive in the reception of the bile, and that it is not a mere receptacle for this fluid. He supposes that the cystic duct acts as an absorbent, selecting from the bile in the hepatic duct its more active ingredients, which are carried into the gall-bladder, where they remain until "some peculiar irritation" of the mouth of the common duct, by the passing chyme or by some other stimulating cause, solicits its discharge, in a gradual manner, for the purpose of purging the intestines. In support of this opinion he refers to the experiments of Dr. Douglas, of the same city, who found that the bile which passed directly from the hepatic duct into the intestines was bland and harmless, and was mixed with the chyme, and thus seemed to aid, as shewn by the very conclusive experiments of Mr. Brodie, in the formation of the chyle, and of the new materials for the nourishment of the body; whilst the bile found in the gall-bladder was always bitter, pungent, and viscid.

These properties, however, of the cystic bile, may supervene without any election being exerted by the cystic duct in the process; for if we suppose, what is most probable, that during the empty state of the duodenum, the bile flows into the gall-bladder, where its more bland and fluid portions are removed by the numerous absorbent vessels with which the gall-bladder and its ducts are provided, and where, during its retention, its elements combine in such a manner as to modify the characters of the secretion, and to render them very different from those which it evinced immediately after its formation,—we have a sufficient reason for the more pungent qualities of cystic bile. It seems by no means unlikely, therefore, that the change takes place in the bile itself within the gall-bladder, and that it is promoted by the temperature and vital influence of the system.

In respect of Dr. Stearns' opinion, that the gradual flow of the cystic bile into the intestines serves the purpose of a gentle purge or stimulus to their functions, it is by no means new; but we have no more proof that it acts the part of a purge, than that it performs the office of an astringent. How is it, if this opinion be correct, that diarrhœa, or a lax state of the bowels, is so often observed during interruptions of the biliary secretion, and especially of the cystic bile?

After the full detail of the results of Mr. Brodie's conclusive experiments, we need not state at a greater length modern views upon the subject. In the note upon the *function of respiration*, we will briefly notice some peculiarities connected with the functions of the liver and conditions of the bile.

OF THE STRUCTURE AND FUNCTIONS OF THE SPLEEN.

(Note N. See p. 89.)

Although considerable attention has been paid to the physiology of the spleen, yet its functions are but imperfectly understood. They have, indeed, been variously explained by philosophers, but all have erred, chiefly in endeavouring to assign to it one definite function only, which they consider it to perform under all the circumstances that influence the body. Thus, Malpighi, Haller, Blumenbach, Richerand, and Foderé, imagine this organ to be subservient in its functions to those of the liver. Hewson believed it to be destined to the elaboration of the globules of the blood. Tiedemann and Gmelin are of opinion that it is intimately connected with the absorbent system, and that it assists the process of sanguification. Haighton and Moraschi consider that it is subordinate to the stomach in the process of digestion; and many pathologists believe that it permits, in consequence of its peculiar texture, accumulations of blood to take place within it during certain stages of disease, and that it thus prevents more vital organs from suffering injury to which they would otherwise be liable. To us, however, it appears more rational, and certainly more consistent with the operations which characterise the economy of the more perfect animals, to view the functions of this organ as intimately relating to those which the absorbent, circulating, and secreting systems perform, and as including several of the operations just specified, to a greater or less extent, according to the influences to which the body is subjected.

In order to learn the nature of the offices

* Journal of Science and the Arts, No. XXVIII.

which the spleen performs in the animal economy, it ought to be our first object to ascertain correctly its structure; this is, however, a matter of great difficulty. The attention of anatomists has lately been particularly directed to the subject, and Home, Heusinger, and Hopfengaertner, have been assiduous in this investigation, without, however, determining the much-disputed point, whether or no this viscus possesses a proper or glandular structure, or is simply a minute and infinite interlacement of arteries, veins, and lymphatics. Sir Everard Home concludes from his researches, that "it consists of blood-vessels, between which there is no cellular membrane, and the interstices are filled with serum and the colouring matter of the blood, from the lateral orifices in the veins, when these vessels are in a distended state, which serum is afterwards removed by the numberless absorbents belonging to the organ, and carried into the thoracic duct by a very large absorbent." Sir Everard considers "the spleen, from this mechanism, to be a reservoir for the superabundant serum, lymph, globules, soluble mucus, and colouring matter, carried into the circulation immediately after the process of digestion is completed."

M. Béclard* has given an opinion respecting the structure of this viscus, which appears to be the most correct yet offered. He considers that it belongs to the class of erectile tissues, and that its structure results from a peculiar arrangement of arteries and veins, similar to that which is found in the penis, the clitoris, and female nipple. M. B. thinks, that the spleen very nearly resembles the cavernous body of the penis, both in structure and in its phenomena; and he considers it not only to consist of erectile tissue, but to be also the seat of a species of erection more or less similar to that of the cavernous body. This viscus, he argues, presents an actual motion of expansion and contraction; and he adduces the three following circumstances under which this takes place. 1st, *In experiments:* when the course of the blood in the splenic vein is arrested in living animals, the spleen swells, but returns to its former dimensions as soon as the circulation through the vein is restored. 2d, *In diseases:* the paroxysms of intermittents are accompanied with an obvious enlargement of this viscus, which subsides as soon as the paroxysm is over. 3d, A similar phenomenon takes place during digestion. The lateral openings of the veins, noticed by Sir Everard Home, seem to confirm the views of M. Béclard respecting the dilatation and frequent inosculation of the venous radicles in this viscus, which are common to it and the other erectile tissues.†

In respect of the *functions* of the spleen we will only adduce those views which possess claims to a favourable notice.

C. H. Schmidt‡ considers that its vasa brevia contribute to nourish and strengthen the stomach; and that, as the blood of dogs deprived of the spleen is found to run speedily to putrefaction, it is concerned in the preparation and assimilation of the elements of the blood, and that it performs an office to the liver analogous to that which the lungs fulfil with respect to the heart.

Professors Tiedemann and Gmelin§ conclude, from their investigations on this subject, 1st, That the spleen is an organ closely connected with the lymphatic system. This is shewn by its being restricted to those animals which possess a separate absorbent system, by the number of its lymphatic vessels, and by the circumstance of the spleen of the turtle being similar to a mesenteric gland. 2d, That a coagulating fluid is secreted in it from the arterial blood, is taken up by the absorbents, and carried into the thoracic duct. This fluid or lymyh, they remark, was seen not only by them, but by Hewson; and they conclude, that the formation of it is the only means by which it is possible to account for the use of the great quantity of arterial blood which flows into the spleen. In answer to the question, — by what means this coagulable lymph passes into the absorbents? they reply,— either there are, in the substance of this organ, particular gland-like bodies, and small spaces or cells, which several anatomists say they have remarked, in which the fluid is secreted and taken up by the absorbents, — or the finest branches of the arteries in the spleen pass immediately into the absorbents, and by this means some part of the arterial blood reaches the absorbents. From a consideration of all the facts obtained by themselves and former investigators, they infer that a connexion subsists between the splenic arteries and absorbents, either directly or indirectly, by means of cells. The secretion of this reddish coagulating lymph from the arterial blood takes place, in their opinion, from the nerves being excited, particularly during digestion; and consequently, by the plentiful secretion, the course of the blood is carried forward in the spleen, which by this means is reduced in size. 3d, That this secreted coagulable lymph, when conveyed into the thoracic duct, is intended to render the chyle similar to the blood. They consider this inference to be proved by at least two circumstances:—1st, That this change actually takes place, for the chyle of the thoracic duct differs from the chyle of the mesenteric vessels, by a closer resemblance to perfect blood; 2d, That when this coagulable matter was by any means prevented from reaching the thoracic duct, this change did not take place. Amongst other proofs which Professors Tiedemann and Gmelin adduce in support of these circumstances, they shew that the chyle taken from the absorbents of the intestinal canal before these vessels have passed through the mesenteric glands, is always white and has no tinge of red, and either undergoes no coagulation, or does so very feebly and slowly. The same fact had been previously shewn by various anatomists, and similar appearances to those which are now to be noticed have been remarked by Dr. Prout. Professors Tiedemann and Gmelin always observed that this fluid, when it is taken from the absorbents which have passed out of the mesenteric glands, is redder, and coagulates more easily and more firmly than the other; and that the chyle in the thoracic duct, above the en-

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* Additions to the *Anat. Générale* of Bichât.

† See the Note, in the APPENDIX, on the Organs of Generation.

‡ *Comment. de Pathol. Lienis.*

§ *Versuche uber die Verrichtung der Milz, &c.*

trance of the splenic absorbents, and after being mixed with the reddish coagulable lymph, appears the reddest, and coagulates very rapidly. The gradual change of the chyle into blood, they argue, seems, therefore, to be a consequence of its passage through the mesenteric glands, and of the admixture of the reddish coagulable lymph supplied by the absorbents of the spleen.

"The properties of the spleen in the fœtus and in old age, support this view. In the fœtus, the spleen is well known to be very small, and no chyle is formed in the intestinal canal in this stage of existence; the spleen, accordingly, intended to assimilate the alimentary matter derived from the intestinal canal, is of no importance. After birth, when the formation of chyle begins, this organ shews itself full of blood, and increases in size rapidly. In old persons, the spleen is commonly diminished; it appears, therefore, like the lymphatic glands, to decrease in size with age."

In order to establish the second circumstance which supports their third conclusion, Professors Tiedemann and Gmelin had recourse to direct experiment, which fully proved its accuracy. They conclude by observing, that pathology furnishes many confirmations of their opinion; and they adduce the instances of scrofula, diseases of the chylopoietic viscera in general, intermittent fever, and abdominal dropsy.*

OF THE MUCOUS COAT OF THE DIGESTIVE CANAL, AND THE FUNCTIONS OF THE SMALL AND LARGE INTESTINES.

(Note O. See pp. 92, 94, 103.)

The mucous membrane of the digestive tube has an amorphous and spongy structure, more or less soft, and of variable thickness. The free surface of this membrane presents, — 1st, Valvules formed of folds of this membrane, of the submucous tissue, and of muscular fibres contained within these folds. 2d, More or less evident depressions, which are generally infundibuliform, cellular, or alveolar; the follicles differ but little from the alveolar depressions; they have a narrow neck more or less lengthened, and a dilated body lodged in the submucous tissue. They are formed of this membrane turned back upon itself, and exteriorly surrounded by dense cellular tissue supplied with numerous capillaries: they vary greatly in number in different situations. 3d, Small eminences called papillæ, and villosities which are situated on the unattached surface of the membrane. These assume various forms, but in general, those in the pyloric extremity of the stomach and in the duodenum, being more broad than long, present a laminated appearance; those of the jejunum are long and straight, and are correctly called villosities; whilst towards the end of the ileum, and in the colon, they re-assume the laminated character. The villosities are semi-diaphanous, their surface is smooth without any appearance of a cellular or a vascular texture, both of which have been imputed to them. Professor Meckel, whilst he doubts whether or not they possess either the one species of structure or the other, is inclined to believe, from analogy with certain parts of some vegetables, that they consist of a continuous series of cells.

The *villosities* of the mucous membrane of the intestinal canal appear to be a mode of structure which, as well as that of folds, *gives an increase of the extent of surface exposed to the influence of external agents.* "Villosities are only more minute forms of membranous folds, differing somewhat from the latter in the greater proportion of the extent of their surface to that of their base, and thus presenting where they exist,—which is chiefly in the small intestines,—the means by which the above-mentioned purpose may be most perfectly fulfilled."

The epidermis, or epithelium, is very manifest at the openings into the digestive canal, but soon becomes much less so as we advance into the cavities, until it is entirely indemonstrable. The blood-vessels and absorbents of this membrane are abundant. Its nerves are chiefly from the ganglial system, but at its natural openings they come also from the cerebro-spinal system.

The *functions* of the mucous membrane of the digestive tube may be enumerated under the following heads:—

1. Absorption, of which the villosities are the most active although not the only agents.
2. Secretion, which is perspiratory and follicular, and of which the products, differing much according to the situation from whence they issue, are generally known under the term mucosity.
3. Tonic contraction, which is promoted by the action of the muscular fibres.
4. Sensibility, varying in all its grades and modes of manifestation.

The mucous membrane of the intestinal canal is next to the first, if not the first, of the

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* The nerves of the spleen are chiefly from the cœliac plexus, and form a reticulum around the splenic artery, accompanying this vessel in all its distributions; a very few minute nerves also come from the *par vagum*, and inosculate with those of the cœliac plexus.

M. Defermon recently found, in his experiments on the abdominal circulation, that the spleen is susceptible of contraction under the influence of various substances which act directly on the nervous system, such as strychnine, camphor, acetate of morphine, &c. In dogs to which he had given strychnine, the spleen, which is usually flat, rolled itself into a spiral form when absorption commenced, and presented very energetic contractions. The action of camphor was different: the spleen under its influence became rugous, and its surface assumed a granulated appearance, producing a degree of motion in the whole organ.

The influence of these agents on a viscus whose nerves are nearly exclusively belonging to the ganglial system, confirms our views respecting the extent of function which we have attributed to this system.

As respects its structure, the spleen may be said to consist of a minute and infinite interlacement of arteries, veins, lymphatics, and soft nerves. Its blood-vessels are endowed with a faculty of dilatation under certain conditions of the system and of the adjoining parts, so as to allow accumulations of blood to take place within it to a very considerable extent, without material injury to itself or to the body.

structures of the body which comes into existence. Its characters are but little modified by age or sex.*

Of the digestive process in the intestines it is not necessary to say much in addition to what is contained in the text. This process, as it respects the whole apparatus destined for its performance, may be divided into three stages, —namely, chymifaction, chylifaction, and fæcation; the first is performed in the stomach, the second in the small intestines, and the third in the large intestines. The first has already come before us, and the second was noticed when the functions of the liver were under consideration. We may, however, remark, respecting chylifaction, that it is by no means a chemical process, for there subsists no chemical relation between the chyme and the biliary and pancreatic juices, which are the materials of the new product; this process is altogether a vital one, and the result is very nearly alike under every circumstance. Chylifaction chiefly takes place in the duodenum and jejunum, from the admixture of the juices just now mentioned with the chyme. The experiments of Professor Mondini confirm the inference, that the duodenum is distended with the chyme when the bile is passing into it.

The absorption of the chyle commences about the end of the duodenum, and goes on throughout the jejunum and the first half of the ileum, and is nearly completed at the termination of this intestine; this function takes place with greatest activity in the jejunum.

When the secretions poured into the duodenum are deficient or excessive in quantity, or deranged in quality, it is obvious that the digestive function in the small intestines must be disordered accordingly. Such disorder is indeed of very frequent occurrence; and the observing practitioner may often be able to trace, by concurrent signs, the specific cause and pathological state. On some occasions he will infer, that the energies of the stomach and duodenum being exhausted, the substances received into them do not undergo the requisite changes, but frequently form new combinations to which their constituent elements are chemically prone, and which irritate and inflame the surface with which they are in contact. On other occasions he will be induced to conclude, from a careful comparison of symptoms, that the secretions which are poured into the duodenum are deficient in quantity, or even vitiated in quality, thus imperfectly performing the purposes for which they are intended. At another time he will rationally infer, that the bile which has been long congested in the ducts, running through the liver, or pent up in the gall-bladder, has been let loose, and, owing to the more acrid properties it has acquired during the term of its congestion, is now irritating the duodenum and small intestines, exciting sympathetically the stomach, owing to the nervous and vascular connexion, and stimulating the whole canal through which it passes, and even exciting the surfaces over which it flows, or with which it remains for any time in contact, to inflammatory action.

Of the functions of the cæcum and large intestines, or fæcation.—The *cæcum*, both as respects its functions and its diseases, is an organ which has not yet received that degree of investigation which it seems to deserve. As regards its functions, certain particulars may be adduced, which appear, both from experiment and observation, to be satisfactorily made out.

The resemblance of the cæcum to the stomach in most of the graminiferous and particularly the ruminating animals, as well as its form and situation throughout all the higher classes of the animal kingdom, are circumstances which sufficiently shew it to be a reservoir in which the last act of digestion is performed. This was the opinion of Viridet,† and it is fully confirmed by the able and recent researches of Tiedemann and Gmelin.‡

The situation of this viscus, its capacity, particularly in some animals, the circumstance of its contents having to advance, in opposition to their gravity, and its attachment to the parietes of the abdomen, are proofs of a much slower circulation of the intestinal contents through it than through any other part of the canal, and confirm the view which has been taken as to its being, in some respects, a reservoir, in which is poured that portion of the materials remaining in the ileum, and which effects the last changes in them which they are destined to undergo for the purposes of digestion and nutrition.

Besides the proofs in support of this opinion which have been now adduced, it may be important to state, that this viscus is abundantly supplied with large follicular glands, which, according to the experiments of Tiedemann and Gmelin, secrete an acid, albuminous, and solvent fluid, which mixes with the remaining aliments poured into it from the ileum, and promotes the digestion of those portions which have withstood the digestive process in the stomach and small intestines, or have been insufficiently changed in their transit through them for the purposes of absorption and nutrition. In order that this office may be more completely performed, the materials poured into the cæcum remain a greater or less time; so that Nature seems to make a last effort, by means of this part of the large intestines, to obtain the remaining nourishment from the intestinal contents.

But, whilst the cæcum performs the last act of digestion, it seems at the same time to commence the first part of *fæcation;* for it is only in the cæcum that the intestinal matters assume a feculent odour. The contents of this viscus are generally of the consistence of a soft *bouillie*, of a brown or brownish-yellow colour, with a

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* See the Note in the Appendix, on the Developement of the Textures of the Fœtus.

† Sed de intestino cæco quidquam dicere præstat, cùm in quibusdam animalibus sit summè necessarium, nempè quibus est amplissimum, forsanque vicem alterius ventriculi gerit; nam glandulis crassioribus donatur, quorum succus solutione heliotropii rubescit, et solutione sublimati albescit, suisque salibus acidis et volatilibus præditum est." — *De Primâ Coctione*, p. 270.

‡ Recherches Expérimentales, Physiologiques, et Chimiques, sur la Digestion, considérée dans les quatre classes d'Animaux Vertébres. Par F. Tiedemann et L. Gmelin, Professeurs à l'Université de Heidelberg, &c. Par A. J. L. Jourdan. Paris, 1826 et 1827.

feculent smell. This odour, according to Tiedemann and Gmelin, proceeds from a volatile oil, which is apparently secreted chiefly in the cæcum.

During these changes which are effected by the cæcum on its contents, an acid and hydrosulphuretted gas is disengaged from them. This gas seems to be generated only in small quantities during the healthy function of this organ; but when the vital energies of the viscus are diminished, and when, consequently, more or less of remora of its contents takes place beyond what they generally experience, this gas is disengaged in much greater quantities; so that it becomes distended to an extent which is injurious to its healthy tone. In many cases it re-acts on the distending power; and thus the flatus, with the other materials contained in it, are propelled along the colon: but on many occasions, and under particular circumstances, considerable opposition is offered to their transit about the right flexure of this latter viscus; and hence it may rationally be inferred, pain and uneasiness are frequently produced in this part of the colon, as well as in the cæcum, giving rise to the belief, in the minds of those who view the ailments of such patients superficially, that they are labouring under hepatic disease. It is true that very frequently the particular condition of the cæcum now under consideration is sometimes complicated with chronic hepatic disorder; but the existence of such complication could not be understood, unless the practitioner was already aware of the nature of the former derangement. When, also, attention is not paid to the first call to stool, an impediment is thus placed in the way of the passage of its contents along the colon, and obstruction and distension of the cæcum are thus either occasioned, or increased if it previously existed.

Occasion may now be taken to observe that, under circumstances which cause the remora or stagnation of those materials in the cæcum which are poured into it from the ileum, not only is there a sulpho-carburetted hydrogen gas disengaged from them, occasioning distension and other derangements; but they experience considerable changes, becoming more irritating and noxious to this viscus itself, and inducing chronic inflammatory action in its mucous coat.

Under other circumstances of protracted disorder of the digestive apparatus, as when acidity is generated in the stomach and small intestines, owing to imperfect digestion of the food; and when the articles of diet or of drink are of an irritating, or stimulating, or otherwise improper kind or quality; and when the secretions from the liver and pancreas, and even from the mucous surfaces of the small intestines themselves, are of an acid or an irritating nature,—then the remora which these materials experience in the cæcum, and the time which they hereby have to act upon its internal surface, are often productive of disorder of its function and of its internal structure.

To the function of the larger intestines may be given the term *fæcation;* because it is in this situation of the digestive canal that the fæcal matter is formed. In its course through the small intestines the alimentary matters are deprived of their chyle, and of a portion of their more aqueous parts: the residue is poured into the cæcum, where its course is more slow, and where it assumes new characters. The fæcal mass, according to the properties which it presents at the commencement of the colon, is evidently composed,—1st, of the residue of the aliments; and 2d, of the excrementitial parts of the secretions poured into the superior part of the digestive tube. The fæces, when they arrive in the rectum, or at the time of their expulsion from the body, are greatly increased by the more solid parts of the secretions poured out upon the internal surface of the cæcum and colon, their more fluid parts having been absorbed. It is, in some measure, owing to the quantity and properties of the excrementitial parts of these latter secretions, which principally proceed from the follicular apparatus of these intestines, that the fæces present distinctive characters.

Gaseous substances generally are found in greater or less abundance in both the small and large intestines. This gas may come from more than one source: it may arise from the change which the alimentary substances undergo in their course; or it may be secreted by the mucous membrane of the intestines. While we would not altogether deny a share in its production to the former, we contend for the latter. We believe that the mucous membrane of the digestive canal may both secrete gaseous substances and absorb them; and we found our belief upon the following circumstances:—1st. We have proofs derived from experiment and observation that gaseous substances are absorbed and given off from the mucous membrane of the respiratory apparatus. 2d, Pathological facts, intimately connected with the functions and properties of this membrane in different parts of the body, support the position. We have, however, no doubt that the changes which the alimentary substances undergo in the stomach occasionally give rise to gaseous products; and we believe that a similar result follows the remora of the excrementitial matters in the colon and rectum. As to the chemical characters of the gaseous substances found in different parts of the intestinal tube, *see Chapter II. of this Appendix.*

OF THE FUNCTIONS OF THE KIDNEYS.

(Note P. See pp. 98—104.)

The latest, and, we think, the most correct examination of the intimate structure of the kidneys was given at p. 97. We now add the latest experiments which have been made in order to ascertain the extent of their functions. MM. Dumas, and Prevost of Geneva, and afterwards M. Segalas, of Paris, found, on examining the blood of living animals whose kidneys had been extirpated, that it contained urea,* the quantity of which was increased in proportion to the duration of life after the operation; whilst this substance could not be detected in the blood of those animals in which the urinary secretion was uninterrupted. The last-mentioned physiologist, moreover, having injected an aqueous solution of urea into the veins of an animal, observed the secretion of urine rapidly increased by it, and this substance so quickly eliminated in the process, that after

* Five ounces of blood contain one scruple of urea.

twenty-four hours it could not be detected in the blood. It seems, therefore, not improbable that the débris of the textures, being carried into the circulation, is converted, by the influence of the organs and vessels through which it flows, into the substance called urea, and that the function of the kidneys is to eliminate it, with other materials, which would be hurtful to the system. These experiments shew that urea is not formed in the kidneys by their appropriate functions, as was believed by some physiologists; but that it, and probably other materials, which are removed from the blood by these organs, are derived from other sources.

According to Berzelius's analysis of the urine,* this secretion contains, in its healthy state, somewhat more than thirty parts in a 1000 of urea; and Dr. Prout has shewn that nearly one half of urea consists of azote;† consequently it follows, that the injurious accumulation of azote in the system is prevented by the action of the kidneys. Hence we observe the great proportion of urea in the urine of those who eat much animal food, in which nitrogen abounds. We may therefore justly conclude, as, indeed, Dr. Elliotson‡ has remarked, that the kidneys are the great outlet for azote, as the lungs and liver are for carbon.

The following facts more closely relate to pathology than to physiology.

In inflammatory fever the urine is red or deep coloured, or even a deep brown, and perfectly transparent until the disease tends to a termination; it then deposits the lateritious sediment, which is of a reddish colour, and consists of animal matter, phosphate of lime, lithic acid, and sometimes lithate of ammonia. According to Dr. Prout, lithate of soda, and purpurates of ammonia and soda, are also present. In intermittents the appearance of the urine varies according to the stage of the disease; but when a paroxysm of ague is over, what is then voided deposits a peculiarly red powder, which has been examined by Dr. Prout, and found to be a distinct acid, which he has named rosacic acid, from its colour. In typhus fevers the urine is loaded with gelatine and urea. It deposits in gouty disorders, as it cools, a large quantity of lithic acid, in the form of red crystals. The urine in hysteria is of a very pale colour; it contains abundance of saline ingredients, but is very deficient in urea and animal matter. In jaundice it is usually of a brown colour, arising from an admixture of bile. In various other disorders, especially those affecting the secreting function of the liver, more particularly when that function is imperfectly performed, the urine very generally presents a brown and muddy appearance, owing to the kidneys having assumed an action in some degree vicarious to that of the liver, and thus removed much of the carbonaceous, and effete materials from the blood usually eliminated by that viscus. A similar appearance of the urine is often met with in those fevers wherein the functions of the liver are much embarrassed, especially in those which are met with in warm climates. In ascites this fluid frequently assumes a yellowish-green colour, and is extremely viscid. It deposits a copious sediment of rosacic acid, mixed with lithic acid, phosphate of lime, and animal matter; and is often loaded with albumen to such a degree, as to deposit it when heated, or on the addition of concentrated sulphuric acid. Those appearances, however, are not constant; they are more generally met with in the acute forms of dropsy. In some cases of rickets, the urine has been found saturated to a high degree with phosphate of lime. Its character in diabetes is well known. Blood is frequently found in the urine; it gives this secretion more or less of a dark colour and muddy sediment. Mucus is also met with in this fluid, during diseases affecting either the kidneys, the mucous membrane of the bladder, or the prostate gland.

OF ABSORPTION.

(NOTE Q. See pp. 110, 111, 116, 117.)

I. *Of absorption from the digestive canal.*—It appears, from the experiments of Tiedemann and Gmelin on absorption, that the lacteals take up the digested and dissolved portions of alimentary substances, and convey them as chyle through the thoracic duct to the blood-vessels; but as odoriferous, colouring, and some saline substances are not absorbed by them, and yet are found in the blood of the vena portæ and in secreted fluids, it necessarily follows, that there must be some other way than the thoracic duct, by which they pass into the blood.

The following are the chief suppositions which have been offered in explanation of the facts:—"Either all the lacteals do not enter the thoracic duct, and part of them join the veins which form the vena portæ, and thus transmit their contents into the blood of the vena portæ; or substances pass directly from the stomach and intestinal canal into the veins; or, finally, both of these suppositions may be true."

These physiologists found, that quicksilver injected into the absorbents of the intestinal canal easily reached the mesenteric veins and the vena portæ, and this communication was found to take place in the mesenteric glands. By means of this communication they explain the appearance of streaks of a substance like chyle, which is perceived in the blood of the vena portæ after taking food,—a fact which has been frequently observed by other anatomists.

Though the passage of chyle into the vena portæ may be explained by this connexion of the absorbents with the veins of the intestines, it would appear, from the experiments, that the passage of odorous colouring and saline substances does not take place in the same way. The presence of alcohol, gamboge, or indigo, could never be detected in the lacteals or thoracic duct, though it was abundantly manifest in the blood of the mesenteric veins and in the vena portæ. They therefore conclude, that the passage of these substances must be effected through other channels, and that these channels must be the radicles of the veins of the intestines. It was found, on examining blood taken

* See the Chapter at the conclusion of the APPENDIX, on the Analysis of the Fluids, &c. of the body.

† Azote, 1866; oxygen, 1066; carbon, 799; hydrogen, 266, = 4000.

‡ Elements of Physiology, by J. F. Blumenbach, &c. Translated and supplied with copious notes by John Elliotson, M.D., &c. &c.

from a branch of the mesenteric vein of a dog, to which sulphuro-prussiate of potass had been given, that no streaks of chyle were present, but the saline matter was perceived. From this, and other experiments, they conclude that the veins of the intestines appear particularly to absorb heterogeneous substances, such as those already particularised, whilst the lacteals take up nutritious matter; and, consequently, that substances taken into the digestive canal may pass into the mass of blood—1st, through the absorbents and the thoracic duct; 2dly, through absorbents, which are united with veins in the mesenteric glands; 3dly, through the radicles, or the commencement of the mesenteric veins, which ultimately form the vena portæ.

MM. Seiler and Ficinus* have more recently repeated the experiments of Magendie and of Tiedemann and Gmelin on this subject, and confirmed most of their inferences, particularly those of the Heidelberg professors.

As it seems established by these and other experimenters, that the vena portæ receives chyle from the absorbents and other substances which are taken up from the intestinal canal by the veins themselves; and as the blood of the vena portæ, into which these materials are conveyed, passes through the liver,—this viscus must be regarded as an organ of assimilation as well as of secretion.†

II. *Of absorption in the lungs.* — Professor Mayer, of Bonn, infers, from experiments instituted in order to ascertain to what extent absorption takes place from the lungs;

1. That animals support a considerable quantity of liquid injected into the lungs, without experiencing mortal symptoms from them; but these injections should be performed by an opening made in the trachea.

2. The symptoms of suffocation, which arise from injections, are not serious when we inject pure water; but they become so when thick fluids, for example oil, which obstructs the aërial passages, or some chemical solutions, which inflame the bronchial surfaces, are employed in this manner.

3. The fluids and solutions injected into the lungs are absorbed more or less quickly according to their nature, and their degree of concentration.

4. This absorption is in general very great, but is less in young and newly born animals than in adults.

5. Absorption takes place by the pulmonary veins, for it has occurred in the space of three minutes; the fluids injected are found in the blood before they are perceived in the chyle; they are found in the left auricle and ventricle of the heart long before the least trace of them can be seen in the right auricle. Lastly, absorption is carried on even although the thoracic duct be tied.

6. Absorption is likewise performed by the lymphatic vessels, but more slowly.

7. The veins of the stomach and intestines also absorb, but in much smaller quantities.

8. The existence of fluids absorbed by the veins can be demonstrated in the blood. It is easy to discover there the prussiate of potass, the muriate of iron, arsenic, &c. The prussiate of potass injected into the lungs can be traced, first in the arterial blood of the heart

* *Journ. Complement. Août* 1824, p. 125, *et seq.*

† See the note on the Functions of the Liver, p. 22.

Having treated of the function which has been considered as properly belonging to the liver, we may also allude to the inquiry already made by us, whether or no this important organ performs any other part in the economy. But before this question can be entertained, it will be necessary briefly to consider the important fact, that a portion of the materials absorbed from the digestive tube is either removed by means of the radicles of the mesenteric veins themselves, or by means of absorbents or lacteals running to these veins, or by a communication existing in the mesenteric glands between the veins and absorbents. Any one of, or even all, these operations may go forward; but that some one of them actually has place in the economy, cannot be disputed, since various heterogeneous matters introduced into the digestive tube, as well as chyle itself, have been very satisfactorily traced into the mesenteric veins, and in the blood taken from the trunk of the vena portæ. The fact, that a portion of the materials taken up from the digestive canal is carried directly into the blood which flows into the portal system, by no means ought to preclude our belief that another, and perhaps a larger, portion of the absorbed materials is conveyed through the lacteal trunks to the thoracic duct. This latter channel, however, seems insufficient for the transport of the whole of the chyle and other matters carried from the digestive organs into the blood; and when viewed as the chief road by which substances received into the circulation can enter, it bears no relation either to the quantity and variety of these substances on the one hand, or to the numerous sources of waste existing on the other, which the former is constantly called upon to supply.

Viewing, therefore, the blood carried into the liver by the vena portæ as containing a considerable portion of absorbed materials, some of them of a more or less heterogeneous description, others of them more or less animalised,—facts sufficiently proved by observation and experiment,—it cannot be considered as stretching the inference beyond what the laws of the animal economy seem to warrant, if we conclude that these materials are assimilated with the blood chiefly during their circulation in the liver, and that, in addition to secretion, this organ performs an assimilating function. Notwithstanding the importance, to the pathologist and practitioner, of ascertaining, as far as is in his power, the real extent of function which the liver performs, it seems to have been utterly neglected. This has been owing to the belief, which was long entertained, as to the medium of absorption of the chyle and other materials from the digestive canal. This function being long supposed to reside in the lacteals alone, and it being considered that the only route by which fluids of any description could reach the blood from the stomach and intestines was by the thoracic duct, the lungs were considered as the only assimilating organ, and no part of this latter operation was imputed to the liver, although every consideration derived from its situation and comparative anatomy seemed to point to it as an important instrument of the process.

and arteries; then, if the injection be continued, in the venous blood.

9. These substances can be discovered in abundance in the urine in the bladder, and in that in the kidneys. The prussiate of potass can be discovered in it seven minutes after the injection.

10. The prussiate of potass is likewise deposited, and even in considerable quantity, in the serum of the pericardium, of the pleura, of the peritonæum, in the synovia, under the skin, and in the milk.

11. When the prussiate of potass is injected, it can be discovered after some hours, not only in the fluids, but also in many of the solids: several of these parts then become green or blue with the muriate of iron, viz. the cellular tissue under the skin, and in the whole body, the fat, the serous and fibrous membranes, the aponeuroses of the muscles, tendons, the dura mater, periosteum, &c.

12. The membranes of the arteries and veins, even the valves of the heart, can be thus entirely coloured blue by the same agent.

13. The parenchyma of the liver and spleen cannot be coloured blue, but sometimes the cellular tissue around their great vessels. The lungs, the heart, and the kidneys, can be coloured blue.

14. The substance of the bones and their marrow, the substance of the muscles and that of the brain, spinal marrow, and nerves, evince no change of colour with the muriate of iron. The nerves of the brain and spinal marrow seem to exert a repulsive and exclusive force, on the contact of fluids foreign to their nutrition. It may be concluded from this, that the opinions of many physiologists, that poisons act mortally when they are applied to these parts of the nervous system, are not well founded, and are devoid of direct proofs.

15. These experiments may also throw some light on secretion, the reproduction and nourishment of bodies; they teach, moreover, the passage of liquids from the mother to the fœtus, When the prussiate of potass has been administered to the mother, it can be detected in the water of the amnion, in that of the chorion, and of the umbilical vesicle, in the liquid of the stomach, in many solid parts of the fœtus, for example in the kidneys, in the stomach, &c. as also in the placenta. When a fœtus, to the mother of which prussiate of potass has been given, is placed in a mixture of spirit of wine and muriate of iron, it becomes blue coloured. Thus we acquire a certain proof of the passage of fluids from the mother to the fœtus, a proof that has been vainly sought for until now:—the fluids taken into the blood of the mother are deposited in the tissue of the placenta, and are thence absorbed by the veins of the fœtus.

III. *Of the manner in which absorption is performed, and of exhalation.*—M. Magendie* infers that the chyliferous vessels absorb chyle only, and that the veins possess the faculty of absorption. He has endeavoured to disprove the absorbent power of the lymphatic vessels, but in this he has not succeeded. He considers also that his experiments justify him in concluding, that in all cases when artificial or real plethora exists, and the veins consequently are distended, no absorption takes place, or only in a slight degree, and after a greater length of time than under ordinary circumstances; whilst, when the original quantity of blood is diminished by venesection, absorption follows in one-fourth of the time in which it is found to occur when depletion has not been previously had recourse to. He considers it, therefore, to follow, that absorption is influenced by the congestion and calibre of the blood-vessels.

The further pursuit of these researches led M. Magendie to the conclusion, that absorption is nothing more than the well-known phenomenon of *capillary attraction*, which takes place when tubes of a small calibre are immersed in fluids,—a phenomenon whose energy is in a direct ratio of the affinity of the fluid for the surface of the tube, and in an inverse ratio with the diameter of the latter.

"It appears to me then," he adds, "beyond doubt, that all the blood-vessels, venous and arterial, whether dead or living, small or great, present, in their parietes, a physical property calculated to account for the principal phenomena of absorption. To affirm that this property is alone able to produce all the phenomena of absorption, would be to go beyond what is warranted by a correct logic; but in the present state of facts on the subject, I know not any thing which weakens the inference that I have drawn, but many which may be adduced in its support.

"By this method of explaining absorption," he observes, "we solve a number of other phenomena in the living system, otherwise inexplicable; for example, the principle on which dropsies are cured, the relief from congestion and inflammation produced by blood-letting, the want of efficacy in medicines during those febrile states in which the vascular system is greatly distended; the propriety of that practice which institutes blood-letting and purging prior to the administration of other active medicinals; the rationale of both partial and general dropsies, under circumstances of cardiac or pulmonary diseases; the use of ligatures upon limbs after the bite of venomous animals, in order to prevent the consequences of such accidents," &c.

That absorption takes place exclusively through the medium of the veins, cannot, in our opinion, be granted to any part of the body or to any organ, excepting to the brain. As respects this organ, we believe that sufficient proofs exist of this function being performed entirely by this set of vessels.†

This very interesting subject has been further investigated by MM. Segalas and Fodéra.‡ The latter Physiologist entered upon a series of experiments, which, although they appear not to us fully to substantiate the opinion of M. Magendie, that venous absorption takes place by capillary attraction, seem, nevertheless, to shew that this process, or one similar to it, actually exists to a certain extent in the living body; and that though it may be subordinate to more energetic influences, it should not be altogether overlooked in our inquiries into the operations of the animal economy.

M. Fodéra's end, in his experiments, has been to demonstrate that exhalation, which he

* *Journal. de Physiol. Expériment* No. I.

† See the Note on the Structure and Functions of the Brain.

‡ *Journ. de Physiol.* April 1822 and January 1823.

calls *transudation*, and absorption, which he names *imbibition*, are similar phenomena, proceeding from the capillary attraction of the parietes of the different vessels, owing to their porosity ; operating, in the first case, from the interior of the vessel to the exterior, and in the second, from the exterior to the interior.

M. Magendie conceived he had already proved that venous absorption takes place by imbibition, and came to the conclusions which we have now stated. One of his experiments consisted in completely isolating a portion of vein, and placing its surface in contact with an active poison : its presence was soon discovered at the internal surface of the vessel. M. Fodéra then inversed the experiment. He injected a poisonous substance, with every proper precaution, into the interior of a portion of artery comprised between two ligatures, and isolated from its cellular tissue, its lymphatics, and its *vasa vasorum :* poisoning took place. He obtained the same result by filling with poison a portion of an artery, vein, or of intestine, removing and placing them either at the surface of a wound made in another animal, or in the abdominal cavity. In these different experiments, the rapidity of the poisoning appeared to vary according to the age and kind of animal, the thickness and length of the portion of vessel or intestine, its greater or less distension, the more or less perfect solution of the injected matter, &c.

M. Fodéra has also seen gases absorbed in the same manner. He placed on the peritoneal cavity of a rabbit sulphuretted hydrogen, enclosed in a portion of intestine removed from another animal ; at the end of some time symptoms of poisoning manifested themselves, and the sulphuretted hydrogen was no longer found in the intestine.

If, in a living animal, an artery or vein is exposed, an oozing is observed to take place through its parietes. This oozing augments if a ligature be applied to the vessel : different dropsies may likewise be produced by the ligature of the great venous trunks.

M. Fodéra concludes, from these facts, that exhalation is only a phenomenon of transudation through the parietes of the vessels, as many physicians had thought before the exhalent vessels were imagined.

The following experiments prove that, at least on the dead body, transudation of liquids may take place at the same time from the interior to the exterior, and *vice versâ*, through the vascular or intestinal parietes. M. Fodéra filled a portion of a rabbit's intestine with a solution of prussiate of potass, and plunged it into a solution of hydrochlorate of lime : he introduced into another portion some hydrochloric acid, and surrounded it with sulphuric acid : finally, he placed a bladder, filled with tincture of turnsol, in a solution of gall nuts. Some time afterwards he found in the interior of these portions of the intestine and of the bladder hydrochlorate of lime, sulphuric acid, and gallic acid, by the tests of nitrate of silver, hydrochlorate of barytes, and sulphate of iron ; and in the liquids in which they had been immersed, prussiate of potass, hydrochloric acid, and tincture of turnsol, by the tests of sulphate of copper, the nitrate of silver, and by the reddish colour of the solution of galls being rendered bluish by the potass.

On injecting at the same time into the pulmonary vein of a sheep a solution of hydrochlorate of barytes, and one of hydrocyanate of potass, into the trachea, M. Fodéra also found hydrocyanate of potass in the pulmonary artery, and hydrochlorate of barytes in the bronchia.

Similar phenomena may be produced upon a living animal. M. Fodéra has found, for example, in the bladder or in the thorax substances which had been injected into the peritonæum ; and in the abdominal cavity substances which had been introduced into the thorax or bladder. In these experiments he employed the solution of gall and sulphate of iron, or rather the latter salt and prussiate of potass.

The black or blue colour, announcing that transudation has taken place, is frequently not observed until the end of more than an hour : it may be rendered almost instantaneous by putting in action the galvanic influence. For this purpose, this ingenious experimenter injects into the bladder, or into a portion of the intestine of a living rabbit, a solution of prussiate of potass, communicating with a copper wire ; externally, he places a cloth wet with a solution of the sulphate, communicating with an iron wire : these wires are put in contact with those of the pile. If the galvanic stream be directed from the exterior to the interior, by making a communication between the iron wire and the *positive* pole, and between that of copper and the *negative*, the tissues of the organs imbibe the Prussian blue : if the stream be changed, the colour appears on the cloth.

M. Fodéra injected into the left cavity of the thorax of a rabbit a solution of hydrocyanate of potass, and into the peritonæum a solution of sulphate of iron ; he afterwards kept the animal placed on its left side for three quarters of an hour. At the end of this period the animal was opened, when he found that the whole of the tendinous part of the diaphragm had imbibed the blue matter : the muscular part was much less tinged, and only in isolated points. The substernal lymphatic glands were likewise blue. The thoracic duct contained a bluish liquid : the peritoneal membrane of the stomach and duodenum was covered with spots of the same colour : they were observable, but in less number, on the rest of the digestive canal, and on the arteries. The lymphatic glands of the mesentery, the suspensory ligament of the liver, and the epiploon, were also tinged blue. Some small sub-peritoneal veins presented a slight blue coloration of the liquid contained in their interior. Twelve hours afterwards, the blue tint of these different parts was much more intense.

The progress of the coloration may be traced, and the phenomenon in some measure be seen in its different *phases*, by injecting a ferruretted solution of prussiate of potass into a portion of the intestine of a living animal, tying both ends, and plunging it into a bath containing sulphate of iron. At first a slight coloration only is observable in the parts, which gradually becomes deeper ; afterwards the liquids of the lymphatics and of the blood-vessels become coloured in their turn. In the latter, the coloration begins by small ramifications, and afterwards extends to the branches, which are observed to be filled with intervals of blood and a blue liquid. In these experiments, M. Fodéra discovered the presence of the prussiate of iron in the lymphatic vessels, in the thoracic duct, and, finally,

in the portion of the inferior vena cava contained in the chest.

M. Fodéra concludes, from these different experiments, 1st, that exhalation and absorption take place by transudation and imbibition, and depend on the *capillarity* of the tissues; 2dly, that this double phenomenon may take place in every part, and that the liquids imbibed may be conveyed equally well either by the lymphatic vessels, or by the arterial or venous. But (the author very wisely adds) the phenomena of exhalation and absorption ought not to be considered as connected alone with imbibition and transudation: the modifications which they experience from the action of surrounding agents, from the nervous influence, the state of rest and motion, the energy of the circulation, the affinities of the substances with the tissues, the derangements produced by disease, and the elaboration which the fluids undergo whilst absorption and exhalation are taking place, ought likewise to be studied.

M. Fodéra endeavours to explain the increase of exhalation in the phlegmasiæ by the dilatation which the parietes of the capillary vessels experience; the interstices of the fibres which form these parietes become at such times increased, and consequently permit a more ready issue to the fluids: the serosity and the white globules, which are smaller than the red, are first effused; at last the red globules themselves occasionally escape. It will be seen that this mode of conceiving the phenomenon does not explain the infinite modifications which the liquids exhaled into the inflamed parts undergo.

M. Fodéra notices cases in which the lymphatics or thoracic duct have been said to contain different substances, which had been introduced either into the digestive canal, the serous cavities, or into the cellular tissue. If the effects of absorption are not manifested in the experiments, where a portion of intestine, containing poison, has no longer any communication with the rest of the body, except by a lymphatic vessel, we must seek for a cause in the extreme slowness of the circulation of the lymph. M. Fodéra inserted some liquid prussiate of potass in the subcutaneous cellular tissue of the thigh and abdomen of two young rabbits. In the first animal at the expiration of a few minutes, and in the second at the end of half an hour, he found it in the lymph of the thoracic duct, in the urine, the mucus of the intestines, the synovia, the serum of the blood, the serosity of the pericardium, of the pleura and of the peritonæum, as well as in all the solid parts, except in the crystalline lens, the cerebral substance, the interior of the nerves, and the osseous tissue. In another experiment the interior of the nerves presented traces of it.

Would not these experiments tend to prove that absorption in these cases had taken place at the same time, both by the lymphatics and blood-vessels?

While the German physiologists have ascribed absorption to the absorbents and veins only, MM. Magendie and Fodéra have extended this function to the arteries also. In this, however, we think that they have been misled by fallacies which had crept into their experiments, and especially by the unnatural position and deranged actions which the operations and agents required by the experiments induce in the animal and in the parts experimented on. From every consideration, we are led to conclude, that the inferences at which Tiedemann, Gmelin, and Mayer, have arrived, approach the nearest to truth.

The experiments performed by Darwin, and more recently by Wollaston, Brand, and Marcet, tend to prove that different substances introduced into the stomach are found mixed with the urine, without having passed by the lymphatic or blood-vessels.

M. Fodéra has repeated these experiments, and made them undergo an ingenious modification, which has discovered to him phenomena unobserved by former physiologists. He introduced into the bladder a plugged catheter, after having tied the penis in order to prevent the urine from flowing along the sides of the sound. He laid bare the œsophagus at the interior part of the neck, and injected into the stomach a solution containing some grains of the ferruretted hydrocyanate of potass. This being done, he frequently removed the plug, and received on filtering paper the urine which escaped. On this paper he dropped a solution of sulphate of iron, and added to it a little hydrochloric acid in order to destroy the colour. In one experiment the prussiate was detected in the urine ten minutes after its injection into the stomach, and in another five minutes afterwards. The animals were opened immediately. The salt was found in the serum of the blood taken from the thoracic portion of the vena cava inferior, in the right and left cavities of the heart, in the aorta, the thoracic duct, the mesenteric glands, the kidneys, the joints, and the mucous membrane of the bronchia.

This important experiment proves the extreme rapidity of absorption; it shews also that the prussiate of potass found in the urine is conveyed thither by the ordinary circulating ways.

The following experiment demonstrates the rapidity of pulmonary absorption in particular. M. Fodéra opened the thorax of a rabbit and removed the heart, immediately after some prussiate of potass had been injected into the trachea. This operation was performed in twenty seconds: the interior of the left auricle, however, presented a bluish green colour, which was more deep at the *mitral* valve, and less apparent in the aorta. The absorption, therefore, seems to take place at the very instant when the injection has penetrated into the subdivisions of the bronchia.

We are of opinion, that to limit the process of absorption in every part of the body, and under every combination of circumstances to which it is subject, to one particular process, or to one particular conformation or property which the vessels, whether blood-vessels or others, may possess, would, in the present state of our knowledge, be to draw an inference not justified by many important facts. On the contrary, it seems more probable, that not only the vital properties, but those of a physical nature, are requisite to the production of the phenomena in question; and that the latter set of properties are under the control of the former.

Instead of attempting to shew that those physical properties for which MM. Magendie and Fodéra have contended, are not, to a certain degree, efficient in the production of the process in question, we would only argue for their subordinate character, which may be proved by evidence still more incontrovertible than that which M. Magendie has adduced in support of

his purely physical properties: but, although the vital properties are chiefly predominant in the operation, yet those for which they contend may have still a place to a certain extent, which extent is modified by a superior influence.

Investigations into the process of absorption have also been entered upon in America. Doctors Lawrence, Coates, and others, made thirty-four experiments in which the prussiate of potass was introduced into the alimentary canal: from these it appears, that articles taken into the stomach may be conveyed into the circulation by three channels; namely, the vena portæ, the œsophageal veins, and the thoracic duct; and if all these are closed, the absorbed matters are no longer conveyed to the circulation or to the urine. With regard to the quantity conveyed by each, they had no accurate means of judging. As the quantity of fluid, however, contained in the vena portarum is so much greater than in the thoracic duct, it follows, that to produce a colour of equal intensity, a much larger amount of the colouring matter is requisite; and as the serum of the blood of the vena portæ gave an equally deep colour, the greater proportion of the materials must have been absorbed through the veins contributing to this system of vessels.

In consequence of reading the experiments of Professor Mayer, of Gottingen, upon absorption in the lungs, Doctors Lawrence and Coates made a few with that reference.

The animals generally died in about a minute after the injection, from suffocation, by the ligatures which they placed on the tracheas of most of them. These experiments, we think, go to favour the idea that absorption from the mucous membrane of the lungs is performed principally by the pulmonary veins. They lay particular stress upon experiments 5th and 6th. In the first, the blood from the left side of the heart indicated the agent in much larger proportion than that from the right side, both being examined about the same time, viz. seven minutes. In the second, where the examination was made in a much shorter period, viz. three minutes and a half, and four minutes and a half, the article was distinctly found in the left side of the heart before it had arrived in any other part of the system.

The effects of infiltration were also remarkable in these experiments.

The results of five trials of the prussiate in the *cavity of the abdomen* are here arranged for inspection.

Animals.	Quantity.	Thoracic Duct.	Carotid and Jugular.	Urine.
Kitten.	Half ounce of solution.	12 & 13 m. distinct blue.	6 m. distinct blue.	19 m. no blue.
Idem.	Idem.	4 m. blue.	2 m. no blue.	10 or 15 m. no blue; 29 m. distinct blue.
Idem.	Idem nearly.	3¾ m. blue.	2 m. no blue.	5 m. blue, not strongly.
Idem.	Half ounce.	3 m. blue.	4 m. strongly blue.	More than 4 m. doubtful.
Cat.	Uncertain.	9½ m. blue.	6 m. no blue.	More than 9½ m. no blue.

The short time in which the prussiate reached the upper part of the thoracic duct in the above cases, induced them to make four other trials, in order to ascertain the earliest period at which that took place. Half an ounce of solution was employed in each case.

In the first animal, a kitten, the salt first arrived at the spot of observation in four minutes, and the quantity gradually increased till seven or eight minutes. In the second kitten, it appeared in two minutes: the serum of this animal gave a blue tinge. In the third kitten in three minutes and a half: serum of blood also blue. In the cat, it first appeared in thirteen minutes.

In these cases, the thoracic duct was cut off near its insertion, and the test applied there. In consequence of this interruption, previously to the prussiate arriving at the upper extremity of the duct, the discovery of the salt in the serum of the blood clearly evinces that it was conveyed there by other channels.

It is mentioned by Magendie, that he has seen, on pressing the lacteal branches so as to discharge their contents in the direction of the trunks, that those branches would again fill themselves after the animal's death. They have also witnessed these appearances; but they do not know of any similar observations to the following made on the lymphatics, or of any evidence of the actual chemical presence of an article conveyed after death into either of these systems from without.

Four kittens were bled to what is commonly considered death. The blood ceased to flow from the divided carotid, and voluntary motion was extinct. Prussiate of potass in solution was then thrown into the abdomen. It appeared at the thoracic duct in five and a half, five, fourteen, and twelve minutes, respectively. In the two last, the great vessels orginating at the heart were secured by a common ligature. The blue colour was in every instance perfectly distinct.

In reasoning upon the subject of absorption, the question has frequently arisen, whether the articles found in the living fluids exist there as chemical substances, or have their chemical nature altered and animalised by the action of the vessels through which they have entered the system. It was, however, deemed a curious subject of inquiry, whether artificial chemical changes can take place in the fluids while they continue to circulate in living vessels, and the ordinary actions of life go on. With a view of ascertaining this point, they commenced by throwing prussiate of potass into the abdomen, and green sulphate of iron into the cellular tissue, in order to try whether the well-known result of their admixture, the prussian blue, would be produced in the vessels. This, however, did not take place; and they resolved to repeat it, by throwing the sulphate, as the article of more difficult absorption, into the abdomen, where this process went on with more facility, and the prussiate into the cellular substance. On performing this, they were gratified by the striking result of a distinct and beautiful blue in the thoracic trunk and its contents, and in nearly the whole substance and surface of the *lungs*. These viscera were preserved in spirits, and are now in their possession. The blood threw up a coagulum of a strong blue colour, and the lymph and chyle from the thoracic duct threw down a blue deposit. Thus, not only a foreign, but a pulverulent substance could present its unnatural stimulus, circulate through the vessels, and accumulate in the lungs, without preventing the actions of life from considerable exertion, and without occasioning coagulation of blood. The animal manifested some difficulty of respiration before she was killed, but walked about without the least difficulty, and uttered no cries, nor other signs of disturbance of its powers. In another case, the urine and lungs were noted as exhibiting a blue colour. The other parts similar to those above enumerated, are not described as being found coloured. In a third, the fluid in the thoracic duct was blue; but not the other fluids examined, nor the lungs. Two unsuccessful trials were also made. In another case the thoracic duct was tied, and the same process repeated. A divided bluish green was here found in the urine; but neither the serum of the arterial blood, nor the lymph of the ductus thoracicus, manifested the blue or green.*

Dr. Barry, in his ingenious researches,† has endeavoured to prove that the pressure of the air exercises the chief influence in the production of absorption from the external surface of the body and surface of the air-passages. In proof of this position, he adduces the results of his experiments, wherein absorption of poisonous matters inserted under the cuticle was arrested by the application of cupping-glasses, from which the air was exhausted. But the effect evidently depends more upon the pressure occasioned by the edges of the glasses upon the parts surrounding that in which the poison is inserted, than upon the abstraction of the atmospheric pressure. The rapid absorption of substances from the surface or texture of the lungs, is also imputed by him to the atmospheric pressure; but it should be recollected, that the circulation of the lungs is particularly calculated to promote the speedy introduction of foreign substances, in a state of solution, into the blood. Matters dissolved in a moist atmosphere, or floating in it, may readily be carried into the vessels, along with the constituents of the air, which are continually passing into them during the process of respiration; and many substances in a state of solution, owing to their

* The attention of the author of these Notes has long been particularly directed to the *modus operandi* of various medicinal substances upon the animal economy; and the results of his experiments and observations led him to consider that a very large proportion of those substances act upon the system by their presence in the mass of circulating fluids, and by their influence on the organs, eliminating them from the blood after they had been absorbed into it. Conformably with this view, he published in the "London Medical Repository" for May 1822, the basis for a classification of the materia medica; and he stated on that occasion, that the operation of medicinal substances on the animal economy may be referred to the three following general heads:—

"Class First. — Those substances which act on the animal economy, chiefly from the local effects which they produce upon the textures and sentient systems to which they are applied, constituting the simplest class of remedies.

"Class Second. — Substances which are absorbed into the circulation, and influence the economy, owing chiefly to their presence in the general mass of the circulation, and to their operation on the organs eliminating them from the blood.

"Class Third.—Substances which produce effects upon the body in consequence of both the primary and secondary modes of action: owing both to their local or primary impression, and to their subsequent presence in the circulation and operation upon the eliminating organs or emunctories."

These classes were divided into orders, genera, and species.

It is not owing to the actual presence only of medicinal substances in the blood, that their influence on disease is produced, but also to their operation on those viscera which eliminate them from the circulation, and prevent them from accumulating in it to a hurtful extent. Foreign substances, when introduced into the mass of blood, act upon the nervous systems, the irritable textures, and the various structures and organs of the body, according to the specific properties which those substances possess; and many of them, in addition to the effects which they thus produce, have a more special operation, during the process of their elimination by the different emunctories of the system, upon these emunctories themselves. These special or consecutive effects are chiefly evident on the urinary organs, on the respiratory apparatus, the cutaneous surface, the digestive mucous surface, and salivary glands. This subject cannot be farther pursued at this place; but the author hopes soon to have it in his power to illustrate fully his views respecting it, in a work which is in preparation for the press.

† Experimental Researches on the Influence of Atmospheric Pressure upon the Blood in the Veins. By D. Barry, M.D., &c. London, 1826.

penetrating qualities, and action upon the animal tissues, will rapidly find their way into the blood in this part of the body; for such solutions, if inserted into the cellular tissue of the organ, must come in contact with divided capillaries in the seat of insertion; and if brought in contact with the surface of the air-cells, it may readily be supposed that the same conformation of parts, which admits of the exhalation of the aqueous and carbonaceous constituents of the blood, and the introduction of the oxygen and azote of the atmosphere, will also permit the imbibition of a penetrating aqueous solution. Hence foreign matters may be considered as finding their way rapidly into the blood circulating in the lungs, independently of their being introduced through absorbent vessels, which doubtless also perform their appropriate functions in this, as well as in other parts of the system.

In estimating the nature of the function of absorption, as performed by particular sets of vessels, physiologists have erred by neglecting to appreciate, in relation to the early stages of this act, the effects which foreign substances have upon the different textures, both during life and after its extinction. Thus saline matters in a state of solution, putrid animal substances, numerous vegetable products in a state of fluidity, act in a most evident manner upon the animal textures, when the animal to which they belong is deprived of life, and whilst they yet retain their specific characters. Saline substances penetrate them quickly; putrid animal matters rapidly destroy their cohesion, and reduce them to putridity, infecting speedily their whole mass; and vegetable and animal poisons also penetrate them quickly, and hasten their solution. Similar effects are observed to be produced upon the textures whilst under the powerful dominion of life, although in a much less degree, and generally to a limited extent. We may therefore conclude, that the foreign matter having thus penetrated the living textures, in the seat of contact, and its vicinity, according to its characteristic effects upon them, either passes into the current of the fluid circulating through the absorbent vessels and veins, owing to its having thus penetrated their coats, where they may be considered as possessed of the greatest tenuity, or it is absorbed by the radicles of the absorbents, and conveyed by them either to the thoracic duct or to the venous branches into which they open, or it may be imbibed directly by the venous pores into the veins themselves. Either of these processes may take place, according to the relation which the absorbed substances may have to the living structures with which it is brought in contact.

To us it appears most probable, that foreign substances do not readily penetrate the internal surface of the digestive tube, owing to the circumstance of this surface being protected by a mucous secretion, which is not readily permeated by other fluids, unless such as possess very evident penetrating properties, and active chemical relations; whilst, on the other hand, substances in contact with the mucous surface of the respiratory organs, especially in the smaller divisions of the bronchia and in the air-cells, where this surface is not thus protected, are much more readily absorbed, and produce their effects with greater rapidity. Such is the constitution of the chyle, and such its relation to the other living tissues, that it cannot be readily absorbed, unless by vessels such as the lacteals commencing upon the mucous surface, and in the villi, by open mouths or radicles, endowed with erectile or vital properties; and, accordingly, we find that it is entirely by means of the lacteals that chyle is absorbed.

OF THE ACTIONS OF THE HEART AND ARTERIES.

(Note R. See pp. 119, 122, 123, 126, *et seq.*)

I. *Of the heart.* *See p.* 119, *et seq.* — The muscular fibres of the heart are more apparent in the fœtus than in the adult; it only participates in the general paleness of muscular textures at that epoch, although it is deeper coloured than they. It is also entirely without fat at this period. In old age the texture of the heart becomes softer and more flaccid than in the young subject, and its parietes thinner; its cavities enlarge, especially the right, and its surface is more charged with fat.

The nerves of the heart have been a subject of interest with physiologists. Since they were investigated by Scarpa, opinions have been tolerably uniform respecting them; and numerous observers have proved the general accuracy of his researches. The cardiac nerves are chiefly derived from the ganglia of the great sympathetic; a few also come from the pneumo-gastric, — but these seem rather to inosculate with the former, than to go directly to the texture of the organ. The cardiac ganglion, situated behind this organ, seems more particularly to preside over its movements, or to reinforce with additional energy whatever it may receive from other sources, especially from the centre of the ganglial system and the other ganglia in the neck and chest. These nerves, according to our own observations, supply the substance of the heart in two ways: — 1st, There are numerous branches which proceed from the different plexuses directly to its muscular texture, and which, dipping between the fibres, give off minute fibrillæ to these fibres next to them in the course of their descent into the substance of the heart. 2d. A large portion also of the nerves of the heart form an envelope of the coronary arteries. A part of these seem to follow the arteries throughout their distributions; but, before the coronary arteries have ramified to a great extent, a part of the nerves surrounding them is detached to the adjoining parts, so that all the nerves which surround these arteries, like a reticulum or sheath, do not accompany the ramifications of the latter to their ultimate subdivisions and terminations in the veins, a portion of them appearing to be detached in numerous and minute fibrillæ to the immediately adjoining fibres. Thus it will be perceived, that the muscular texture of the heart receives directly and mediately a very considerable portion of ganglial nerves; whilst it may be presumed, that it also receives an accession in those fibriles which terminate with the nutritious capillaries in this particular structure.

The functions of the heart, it may reasonably be supposed, are chiefly the result of the influence which this disposition of the ganglial system of nerves bestows on its structure. In addition to the support which this inference derives from the conformation of the viscus and its relations with the rest of this particular sys-

tem of nerves, both in man and the lower animals, experiments which have been performed by different physiologists prove its accuracy:* and prove it the more conclusively, inasmuch as they were performed with a view of establishing a different proposition.

But, although the heart derives its chief influence from the ganglial system, (see p. 13, par. 13, *et sequen.*) it is acted on through the medium of the nerves which communicate between this system and the cerebro-spinal, and which seem to convey an additional influence from the latter to the ganglia and plexuses which immediately supply the heart. And as this communication is more intimate in the more perfect animals, and the functions of the cerebro-spinal system are more energetic in them, so it appears to follow, that the heart's action is more readily influenced either by the increase or diminution of these functions in them, than in the lowest orders of animals.

Another point to which it is necessary to advert, is the question as to the active dilatation of the heart — a function of this viscus much insisted on by Hamberger, and more recently by Carson and others. We doubt not that it actually exists, to some extent, in all animals provided with a perfect heart; but we do not believe that it takes place with great energy. If the dilatation, however, of the heart were a mere result of a relaxation of its fibres, its cavities could not be so quickly and perfectly filled by the mechanical pressure of the blood directed towards them, as we observe that they are; and dilatation would be only the consequence of this pressure, and be proportionate to it. But this is not the case; for, as far as we could judge from observing the circulation in fishes, the dilatation seems to precede the flow of blood, the latter appearing as a consequence of the former.

Allowing, therefore, that the dilatation of the cavities of the heart takes place to a certain extent — an extent which it is difficult fully to determine, but which we consider much less than that contended for by Hamberger and Carson,—one of the causes of the flow of blood in the large veins will be apparent.

The heart is perfectly *insensible* in its natural state. This was satisfactorily shewn in an operation performed by M. Richerand in 1813, wherein he divided the ribs, and removed a portion of scirrhous pleura, thus allowing the pericardium to be exposed. The patient was perfectly insensible of any impression when M. Richerand touched this organ, although the pericardium, the part through which it was handled, is evidently the most sensible part of it during disease: in a state of inflammation its organic sensibility becomes indistinctly and obscurely developed.

II. *Of the arteries*, p. 126. — The arteries throughout the body are surrounded by the ganglial nerves. These nerves form a reticulum around them, from which reticulum very minute fibrillæ are given off and dip into their fibrous or muscular tunic.

This particular disposition of the ganglial nerves on the arteries ought to be kept in recollection when we inquire into the functions of the latter. How far it tends, not only to the discharge of the more manifest actions which the arterial system performs, but also to those insensible changes which the blood undergoes in health and in disease, and to the assimilation of the chyle and other absorbed materials conveyed into this fluid, we have ventured to state at another place.† We shall here merely take notice of an opinion relative to the operations of this class of vessels in the circulation of the blood, lately contended for by M. Magendie. This physiologist has inferred from his researches on the circulation:—

"1. That neither the larger nor the smaller arteries present any trace of irritability.

"2. That they are dilated during the heart's systole.

"3. That they are capable of contracting themselves with sufficient force on the blood they contain, so as to propel it into the veins.

"4. That the blood in the arteries is not alternately at rest and in motion; but that it is, on the contrary, in a continued succedaneous (by little jets) motion in the trunks and ramifications, and uniform in the smallest ramifications and divisions.

"5. That the contraction of the left ventricle of the heart, and the elasticity of the larger and smaller arteries, furnish a satisfactory mechanical reason for these phenomena.

"6. That the contraction of the heart and arteries has a considerable influence on the course of the blood through the veins."

We cannot concur in these conclusions, especially in the sweeping inference which forms M. Magendie's fifth proposition; and we might, were it consistent with our limits, point out various fallacies in his experiments, to some of which, indeed, all experiments on living subjects are more or less liable, viz. the unnatural position of the animal during their performance, and more particularly as respects the operations of the part immediately its subject. If M. Magendie limits the process to the mechanical means indicated above, we would ask, how he accounts for the influence of mental emotions in determining the action of the vessels in particular parts of the body? How the diversified influences of numerous external agents on the circulation can be explained? Wherefore so very opposite effects are produced upon the arteries when one extremity is placed in a pail

* Willis divided the eighth pair of nerves in the neck with a view of paralysing the action of the heart, but death did not supervene until some hours, and, in some cases, not until several days, after the operation. In the experiments of M. Légallois and Dr. Phillips, destruction of the brain and spinal marrow did not necessarily and immediately put a stop to the action of this viscus, although, as should be expected, it was greatly influenced by the privation of a necessary and an accustomed influence. In experiments which we performed on several species of fishes, the actions of the heart continued long after the destruction of the cerebro-spinal masses, and frequently for a short time after it was removed from the body. Lastly, fœtuses have been born, in which the action of the heart and circulation were perfect, although they wanted both brain and spinal chord; and many of the lower classes of animals have continued to live for a very considerable time after decapitation.

† See pp. 30, 31.

of ice, and another in a pail of warm water? How can he reconcile his conclusions with the very satisfactory experiments performed by Sir Everard Home, Dr. Hastings, and others? and how can he account for the determinations of blood to particular parts, whilst a diminished quantity is sent to other situations?—if he discard the predominating or vital power which the vessels themselves, and especially their smaller ramifications, possess in virtue of the particular structure already noticed. We readily grant that the larger branches of arteries evince little or no contractile action, particularly in their natural state; but we contend that it increases as we advance towards the extreme capillaries, the action of which derives the blood to them in larger proportion, and thus increases both the mechanical and vital properties of the larger branches supplying them.

We allow that the properties for which M. Magendie contends have an actual place in the process of arterial circulation; but they are not the only ones; they are insufficient of themselves to accomplish the purposes which he assigns to them; and, moreover, they are secondary to, and controlled by, a superior influence.

From these observations it may be perceived that the arteries act in the process of the circulation, not by means of a contractile action similar to what is performed by the heart; nor yet by means of elasticity only; but by an organic or vital operation, which is nearly imperceptible in the larger arterial branches, but which increases as we advance to the extreme capillaries; whilst, on the contrary, the elastic or mechanical properties augment as we proceed in the opposite direction.

OF THE FUNCTIONS OF THE CAPILLARIES.

(Note S. See p. 134.)

This class of vessels may be divided into two orders, performing distinct functions:—1st, Those capillary vessels between the terminations of the aortic arteries and the commencement of the veins of the body; and 2d, Those between the termination of the pulmonary arteries and veins of the same name. The first of these orders is disposed, in different proportions, to the compound solids of the body; the second is distributed on the surface of the air-cells of the lungs only. In the one are performed changes which render the blood unfit for the purposes of the animal economy; in the other takes place an elaborative process of an opposite nature. In the first are produced those organic functions which relate more directly to the nourishment of the frame, as digestion, secretion, and nutrition; in the second, those preparatory operations on the blood which enable the sensible and contractile textures of the body to perform their offices. Without the accomplishment of the latter, the former could not be performed; for as the former depends upon the vital influence distributed to the capillaries and to their respective organs, as well as upon its state in the sources whence it is derived, so does this influence itself depend upon the operations which take place in the latter order of capillaries. The importance, therefore, of these operations in the animal economy must be manifest, as well as the intimate bond which unites them throughout the frame: without the performance of the one class of functions, the other could not be discharged.

This part of the circulation, the most interesting, perhaps, of any to the physiologist and pathologist, without being independent of the heart's action, is the least under its control; the functions of the capillary vessels continuing to a certain extent, even after the heart has ceased to contract. And, as has been shewn by some experiments* performed in this country, in France, and in America, these actions are not limited, even then, to the mere circulation of the fluid which they contain; for under this particular circumstance, they may also perform, for a short time, the functions of absorption and secretion.

These phenomena may be readily explained when we consider two circumstances:—1st, The source whence the capillaries derive their functions; and 2d, the kind of death which the animal experiences, and the order in which the different organs cease to act. We cannot enter here further into this topic; we have pointed out the way, those who are interested in it will be able to pursue it; those who are not, would profit little from a lengthened explanation.

Before we leave this subject we may notice an opinion which has been entertained among the most eminent physiologists. This relates to the existence of subordinate sets of minute and colourless arterial capillaries, each devoted to a particular function; namely, one to nutrition, another to secretion, and a third and principal set to the transmission of the red blood, which, in consequence of the functions of the former two, have become possessed of venous properties. The first and second of these sets are considered to be pellucid in their natural state, and, although they cannot be satisfactorily demonstrated in this state, their existence seems to be rendered probable, if not proved, by many of the phenomena of disease, and by artificial injections.

Dr. Alard has lately contended for the existence of a similar set of colourless vessels connected in the same manner with the veins; and that whilst those of the arteries carry the fluids intended for the nutrition of the textures, for the secretions and exhalation,—these belonging to the veins perform the functions of absorption. Some of these latter vessels, whose open mouths are present every where, in the most intimate textures of the organs, as well as on the surfaces of the great cavities, are supposed by Dr. Alard to terminate in the parietes of the adjacent veins; while others unite and form the trunks which are generally known by the name of absorbents. The discovery of Dr. Fohmann, of Heidelberg, of a communication of the lymphatics of the intestines with the mesenteric veins in some animals, concurs to support the proposition of Dr. Alard. On this subject Dr. Hutchinson, whose physiological knowledge is of the first order, has justly observed:—The view of Alard,—that supposing the existence of minute pellucid vessels springing from the parietes of the small arteries; distributed to every part of the body; conveying different fluids, and producing different effects, according as their vital properties are modified; having corresponding vessels, which spring

* See pp. 37, 38.

from the most intimate texture of the organs and surfaces of the great cavities, and unite in larger tubes, forming in some instances long continuous canals, denominated absorbents, in others running to be inserted into veins, — is one which is qualified to explain, more plausibly than any other, the mechanism of the distribution of the fluids for the purposes of the organic functions ; and is, besides, capable of obviating the difficulties which have been presented by the diversity of the results of the experiments of Hunter, Magendie, Brodie, and others, relative to the mechanism of absorption.*

OF THE VEINS.

(NOTE T. See pp. 135, 137, 139.)

1. As to the precise way in which the veins commence, opinions have been various. At the place where the capillaries change from arteries into veins, there appears to be no reason to suppose the existence of either interspace, or vesicular or spongy structure. The inflected canal of the artery seems to be continuous with the vein. Whilst, however, this conformation is allowed by nearly all, some consider, with Mr. Ribes, that the veins have another commencement in addition to this ; and that a certain proportion of their radicles commence in open mouths or in the pores or areolæ of the laminous tissues, and in the substance of the organs. Others also suppose, with M. Alard,† that some of their roots commence in pellucid lymphatic absorbents.

The structure of the erectile tissues, as the penis, the clitoris, the spleen, &c. seems to support the opinion of M. Ribes, (which is also that of M. Meckel,) who farther supposes that one cause of the difference of the appearance and functions of organs may be ascribed to the extent to which the veins originate in the particular manner for which he contends.

The views of M. Alard derive their chief support from the phenomena connected with absorption ; but, although they appear probable, they cannot be fully demonstrated.

The veins receive but a small proportion of nerves, and these are chiefly from the ganglia. The nerves supplying the pulmonary veins come principally from the anterior pulmonary plexus.

2. *The functions of the veins are*, — 1st, to bring back the blood from the capillaries to the heart ; 2d, to receive and assist in the assimilation of the fluids, which are absorbed by the lacteals and absorbents ; and 3d, in certain situations, and under certain circumstances, to co-operate in the function of absorption.

The *first* of these operations is performed by means of the vital action with which the veins are endowed, assisted by the *vis à tergo* proceeding from the vital action of the capillaries, —by the contraction of the surrounding muscles viewed in connexion with the direction of valves, with which they are provided, — by the pressure of the atmosphere upon the surfaces of the body, — and by the active dilatation of the cavities of the thorax and heart, which draws the blood into the large venous trunks and auricles.

The *third* action of the veins, or venous absorption, seems to be proved by the researches already detailed.‡ The venous radicles, either immediately or mediately, seize the absorbed materials, and convey them into the current of the circulation. This seems to be a vital or organic action, which is probably assisted, in some parts of the body, and under certain circumstances, by the physical property of imbibition, or capillary attraction, which all animal textures evince in a greater or less degree, even during life, according to the penetrating properties of the substances absorbed. It should, however, be recollected, that this physical property is a very subordinate one to vitality, is entirely under its control, and takes place very imperfectly when this influence is in full vigour.

The *second* function of this class of vessels is the admixture of the absorbed vessels, and the assimilation of them. The former or mechanical part of this function is performed generally throughout the body, although it takes place to a greater extent in some instances than in others, as in those viscera in which the blood circulates more immediately after it has received the chyle and lymph from the lacteal absorbents and thoracic duct. Hence it chiefly takes place in the heart itself, and in the liver and lungs. The latter part of this function, the assimilation and animalisation of the absorbed matters, is essentially a vital action, and appears to us to result from the vital influence derived from the nerves with which the blood-vessels are provided. Supposing this position to be correct, we should expect that the vessels in which this process takes place would be most abundantly supplied with those nerves whence we consider the assimilating influence to proceed. Now this is actually the case ; the blood which is carried into the portal veins contains a larger proportion of absorbed and imperfectly assimilated materials than the blood in any other organ ; and this particular order of veins, whose office it is to assimilate them, and to eliminate the effete elements from the circulating fluid, is provided with a much greater number of ganglial nerves than any other part of the venous system ; and, indeed, even more than the arteries in some situations. This particular set of veins, therefore, performs a double function, viz. of assimilation, and of secretion ; in the latter action, however, it may only

* See the Note on Absorption.

Admitting fully the justness of Dr. Hutchinson's remarks, we must observe, that the existence of the sets of capillaries here contended for by Dr. Alard is not proved demonstratively. Indeed, we possess this species of proof in favour only of one set of capillaries, — namely, those which constitute the termination of the arteries and commencement of veins. We know that secretion, nutrition, and absorption, are functions of capillary vessels. This has always been granted, from the time of Hippocrates ; but there have been various instruments allotted to the process ; some physiologists insist, with Dr. Alard, upon the existence of subordinate sets of capillaries allotted to each function ; whilst others contend, with M. Richerand, that they take place through the medium of lateral pores in those capillaries which communicate directly between the arteries and veins. These veins will come under consideration in the notes in this *Appendix* on *Secretion* and *Nutrition*.

† See the preceding Note.

‡ See Absorption, in the APPENDIX.

participate with the hepatic artery ; for, as the hepatic vein returns the blood of both the vena portæ and the artery, the biliary secretion may, probably, not take place until the terminating capillaries of both have given rise to the radicles of the vein.

Assimilation goes on in the next degree of activity in the lungs, and more or less partially in other organs of the body.

OF THE MECHANISM OF THE RESPIRATORY ORGANS.

(Note U. See pp. 144, *et seq.*)

I. *Of the structure of the lungs.*—According to the observations of M. Magendie, the cellules of the lungs do not appear to be arranged in a methodical manner, nor to have membranous parietes. With respect to the non-existence of the latter, we think that he was betrayed into error by the method of investigation which he adopted.* These cellules seemed to him to be formed solely by the minutest and last ramifications of the pulmonary artery ; by the radicules of the veins of the same name, which are a continuation of the former ; and lastly, by the numerous anastomoses of all these vessels. These cellules are separated into many distinct lobules, in each of which the cellules communicate among themselves ; while between the lobules there is no communication.

The number of cellules is in an inverse ratio to the age of the subject ; consequently, the older the person, the larger is each cellula, or, what comes to the same thing, the fewer are the cellulæ.

It follows, therefore, that the lungs become specifically lighter as we advance in life ; and in support of the correctness of this inference, M. M. states that he found, by actual experiment, that, in equal volumes, a portion of the lungs of a man at seventy was fourteen times specifically lighter than that of a child a few days old.

The most accurate description of the bronchia and air-cells of the lungs is given by Reisseisen.† He states, 1st. That the ramifications of the bronchia are more and more numerous as they decrease in diameter ; and that the ultimate twigs end in close bulbous extremities, or air-cells, and that these cells do not communicate with each other directly, but only through the medium of the extreme twigs, of which they are the terminations. 2d. That these ramifications and cells, as proved by Malpighi, have no communication with the surrounding cellular substance. 3d. That these ramifications and cells consist, 1st, of *mucous membrane ;* 2d, of a coat of *elastic white* fibres, on which the elastic properties of the bronchial ramification depend ; 3d, of *muscular fibres*, placed transversely, relatively to the course of these canals. 4th. That the ramifications of the bronchial and pulmonary arteries freely anastomose both in the air-passages and in the surface of the lungs, and that the bronchial arteries chiefly run direct to the pulmonary veins. 5th. That the air-passages and blood-vessels of the lungs are most abundantly supplied with nerves from the par vagum, whose conjunctions with the sympathetic take place externally to the lungs.

II. *Of the action of the glottis.*—M. Bourdon‡ considers that the glottis performs the following functions, in addition to those which are requisite to the formation of the voice.

1. That it is the glottis which suspends respiration during considerable efforts, in opposing by its closure the escape of the air contained in the lungs.

2. Without the glottis, the action of the abdominal muscles would be constantly employed in producing respiration : neither compression of the viscera, nor flexure of the trunk, could be produced.

3. There exists a real *consensus* of action between the glottis and the abdominal muscles, and, through this medium, between the glottis and the different reservoirs, the bladder, the rectum, the stomach, and the uterus.

4. The glottis does not confine its action to the production of the voice ; but by the aid of the sympathetic connexions which unite it to the abdominal muscles, charged to concur in, if not to preside over, important functions, it excites the greatest influence on those functions themselves.

5. Lastly, in the different efforts there is a tendency to expiration, to the production of which the closure of the glottis is an obstacle.

III. *Of the state of the lungs during respiration.* — According to Dr. Carson, a principal part of the mechanical operation of respiration is performed by the lungs themselves, and as follows :— After premising that the substance of the lungs is possessed of elastic properties, and is kept in a state of distension after birth by atmospheric pressure,§ Dr. C. considers that, during inspiration, the intercostal muscles raising and drawing out the ribs, and the diaphragm contracting and descending, create a tendency to vacuum in the thoracic cavities, by enlarging their capacity : but this vacuum is prevented by the rushing of the air into the lungs, the pressure of the air overcoming the elasticity of the organ, and causing it to fill the enlarged thorax. Inspiration is thus effected. But the diaphragm and intercostal muscles having enlarged the thorax, and ceasing to act, the substance of the lungs is enabled to exert its elasticity, recovers its dimensions, and thus expels the additional volume of air just inspired, the passive respiratory muscles following the collapsing lungs, owing to the atmospheric pressure in the external surface of the trunk. Expiration is thus produced.

Dr. Carson seems to err in imputing the function entirely to the causes now stated, and explaining expiration by means of the elasticity of the lungs only. The elastic property of

* He partially filled the lungs by insufflation after their removal from the subject, and allowed them to dry. When quite dry, he found this sort of preparation to be nearly transparent, and readily cut into thin slices with a knife.

† F. D. Reisseisen, M.D., Strasburg. *Uber den bau der Lungen, eine von der Königlichen Academie der Wissenshaften zu Berlin gekrönte Preisschrift.* Berlin, 1822.

‡ *Recherches sur le Méchanisme de la Respiration, &c.* Paris, 1820.

§ As admitted by Haller and other physiologists, and as shewn by experiments on various animals, and by puncturing the walls of the thorax ; when the lungs, if healthy, always collapse, the atmospheric pressure within and without the lungs being then balanced.

the organ certainly exists to a small extent, and performs its part in the operation; but to us it seems to be merely a part, and that a small one; for the muscular contraction of the bronchia, as instanced by Haller and Reisseisen, have evidently a share in producing the phenomenon, as well as the elasticity of the cartilages, and the contractions of the abdominal muscles, as contended for by those who explained the mechanism of the function before the time of Dr. Carson. It should, however, be stated, that the cartilages of the ribs are liable to ossification, and that the abdominal muscles are nearly passive, unless during forced expirations, when the lungs are emptied to the utmost.

The experiments and opinions of Dr. Carson have had the effect of directing the attention of physiologists to the state of the lungs themselves during respiration, and under the various influences to which they are usually subjected either by accident, by operations, or by disease. Dr. Carson had inferred from his experiments, that it is possible to collapse one of the lungs, and to retain it in that state *ad libitum*, by keeping open the communication between the cavity of the chest and the external air; and further, that upon allowing the opening to close, the lung, in a given time, will recover its wonted function, — thereby rendering it practicable, when conceived necessary, to place the opposite lung under the like discipline. In order to examine the stability of these inferences, Dr. David Williams, of Liverpool, instituted several experiments, in the presence of Dr. Trail and others, which contradict some of the chief positions held by Dr. Carson. After detailing his experiments, Dr. Williams draws the following conclusions from them :—

1. That a lung will not collapse from exposure to the atmosphere as long as respiration is carried on by the opposite one, and the auxiliary respiratory powers are not restrained.

2. That a lung possesses for a time, independently of the influence of the diaphragm and intercostal muscles, if respiration is carried on by the opposite lung, a peculiar motive power, the sources of which I do not pretend to explain.

3. That a sound lung soon regains its full power of expansion, when the pressure of the exterior air is removed.

4. That air freely and uninterruptedly admitted into both cavities of the chest simultaneously, through tubes of a certain calibre, will not collapse the lungs, if the auxiliary respiratory organs are unrestrained.

5. That air admitted into both the cavities of the chest (of a middle-sized dog) simultaneously through apertures of an inch and better in length in the intercostal spaces, will not collapse the lungs, provided the animal is allowed unconfined the use of his respiratory organs.

6. That a sound lung never fills the bag of the pleura.

IV. *Of the effects of respiration on the circulation of the blood, especially through the veins.*— The experiments of Haller, Lamure, and Lorry, and subsequently those of Cloquet and Bourdon, have shewn,

1. That, during inspiration, the blood of the vena cava, superior and inferior, is drawn towards the heart.

2. That, during expiration, the blood, is, on the contrary, driven in the same veins towards the viscera.

3. That the arterial blood is also driven towards the viscera at the time of expiration.

4. That the alternate motions of the brain are owing to the changes caused by respiration in the flow of blood.

5. That all these changes are but little marked in ordinary respiration; but that they become very evident in full respirations, and particularly so during great efforts.

6. Lastly, that during great efforts the glottis is firmly closed, the air contained in the lungs is compressed, as well as all the pectoral and abdominal viscera.

In order to ascertain the precise effects produced by respiration on the venous circulation, M. Magendie instituted a set of experiments from which he draws the inferences, that respiration modifies the venous circulation;—1st, by the influence which it exerts on the course of the arterial blood; — 2d, by its direct action on the current of blood in the veins. That in profound respirations and violent efforts, the circulation appears nearly suspended.

The six propositions given above, seem to convey a brief and correct statement of facts. The inferences of M. Magendie are perhaps carried a little too far. The pressure of the atmosphere upon the surfaces of the body, and the actions of respiration, have been adduced by Dr. Carson and Dr. Barry to explain the phenomena of the venous circulation, and whatever suctive action the heart may exert. That the atmospheric pressure remaining constant on the body generally, while it is slightly diminished about the heart, during inspiration, produces a small disturbance of the uniformity of the venous current near the chest, has always been admitted, as just stated; but that this circumstance is productive of effects such as Dr. Carson and Dr. Barry impute to it, cannot be allowed. Dr. Barry considers that, in consequence of the enlarged state of the thoracic parietes during inspiration, and tendency to a vacuum, the pericardium is drawn out, and with it the parietes of the venous sinuses of the heart, and the large veins, just before they open into these situations. Hence the blood during every inspiration rushes into these parts, which become the reservoir from whence the cavities of the heart are replenished; and the suctive influence thus occasioned in consequence of the pressure of the air being thus taken off this part of the vascular circle, being the cause of both the progression of the blood in the veins, and of absorption.

That some slight influence of the kind now stated may be occasioned by the violent and forced respirations observed in the living animals on which Dr. Barry performed his experiments, we will not dispute; but we believe that, during the healthy and usual state of respiration, little or no effect upon the circulation beyond what was already admitted, is actually produced; for we believe that no such tendency to vacuum is ordinarily occasioned in a healthy state of the lungs, and whilst, from the pressure of the air within them, they are enabled to follow the motions of the respiratory apparatus.

Upon this subject, the remarks of Dr. Arnott, in his valuable work,* seem to us, upon the

* Elements of Physics, or Natural Philosophy, General and Medical, &c. By Neil Arnott, M.D., &c. London, 1827. p. 528.

whole, correct, although even here various concomitant relations are overlooked. This author states it to be "a physical impossibility, that a sucking action of the heart or chest can be a cause of the blood's motion along the veins. 1st. The veins are pliant tubes, free to collapse, and no pump can lift liquid through such. 2d. The *suction power* of the chest in healthy respiration is too weak to lift liquid even one inch through tubes of any kind."

In respect of the first proposition, we grant its accuracy upon the main; but it should, in justice to the exact state of the case, be remembered, that the parietes of the veins are so intimately connected to the parts surrounding them, as to furnish a mechanical resistance to collapse from a slight suctive influence, and that hence such influence may be productive of a slight or partial effect, especially when the vessels are kept full at the time of its operating by other causes, as the *vis à tergo*, and the vital influence of the system, which latter has been too much kept out of view, both by Dr. Barry and by Dr. Arnott. As to the second proposition, we do not dispute its accuracy.

There are various circumstances which militate against the hypothesis of Dr. Barry, besides the fundamental one now alluded to, such as the circulation and absorption in the fœtus, the circulation in the vena portæ, and the circulation in animals not possessing one distinct respiratory cavity.

V. *Of the effects of suspended respiration on the circulation.* — From the experiments which were made by Dr. Williams, of Liverpool, on this subject, he deduces the following corollaries:—

1. The blood is obstructed in its passage through the lungs, on suspension of respiration, while its circulation through the other parts of the body continues.

2. The obstruction of the blood in the lungs, on suspension of respiration, is not occasioned by a mechanical cause. This is proved by the flow of blood through the lungs being suddenly arrested, without any subsidence of this organ, while the circulation was carried on vigorously through the other parts of the body, in the experiments detailed by the author.

3. The obstruction of blood in the lungs, on suspension of respiration, arises from the deprivation of pure atmospheric air.

4. The blood which is found *post mortem* in the left auricle and ventricle is the remnant after the last systole, and the subsequent draining of the pulmonary veins.

5. The obstruction of blood in the lungs on suspension of respiration, is one of the principal causes of the vacuity after death of the system circulating arterial blood.

6. The immediate cause of the cessation of the action of the heart is a privation of its natural stimulus, arising from the obstruction of the blood in the lungs.*

OF THE CHANGES INDUCED ON THE AIR AND THE BLOOD BY RESPIRATION.

(NOTES W. See pp. 150—158, 163, 201.)

1. *Of the production of carbonic acid during respiration.*—The experiments of Mr. Ellis and others have led physiologists to conclude, that oxygen is not absorbed by the blood in the lungs from the air during respiration, but that the blood gives off its superabundant carbon from the surface of the air-cells, and the carbonic acid is thus formed in the lungs themselves.

This mode of accounting for the changes induced upon the air and upon the blood during respiration, has been very generally adopted in this country; while the former mode of explaining the process (that which is given in the text) has still been received, with various modifications, on the continent.

It appears to us that the production of carbonic acid gas by the respiratory function has been ascribed too exclusively to one of the above processes; and that it has been too generally viewed as altogether a chemical phenomenon. When the theory of the absorption of oxygen was dismissed, in favour of that which contended for the discharge of carbon from the blood, either in its pure state, or in that of a hydrate, no participation in the process by which the carbonic acid is formed, was allowed to the previously received opinion: however, it still appears a matter of doubt how far either function predominates; for we are inclined to think that both operations go on simultaneously, and that, whilst a portion of the carbonic acid gas is given out from the blood, already formed, it is accompanied with another portion of free carbon, or an oxide of carbon, or even with a hydrate of the same substance, which combines with an additional quantity of oxygen in the lungs, and thus forms the whole of the carbonic acid in question; and that, at the same time, a portion of oxygen is absorbed which combines with the carbon in the blood, and there generates the carbonic acid gas, or the oxide of carbon, which forms a part of the matters discharged from the blood in the lungs. These processes may vary, and either may predominate, according to the state of the vital influence at the time, under whose control they are immediately and completely placed.

This view of the phenomenon in question seems to be fully supported by the experiments of Dr. Edwards, of Paris. They prove that the carbonic acid gas does not form instantaneously in the lungs through the action of the respired air; but that it appears to be secreted to a considerable extent from the blood in the respiratory organs.

As to the quantity of this gas which is formed during respiration, different physiologists have estimated it differently. Godwin considered that for every 100 cubic inches of atmosphere respired, there were given off 10 or 11 of carbonic acid. Menzies, from experiments made with much accuracy, found the quantity of carbonic acid to be about 5 in the 100. Dr. Murray considered it to vary from 6 to 6·5. Sir H. Davy from 3·95 to 4·5. Messrs. Allen and Pepys from 3·5 to 9·5. They estimated the mean at about 8. Dr. Prout found it to be about 3·45. Dr. Fyfe about 8·5. The discrepancies which are remarkable in these results of the experiments performed by these physiologists, doubtless arose, in a great measure, from the different proportions of this gas produced by different individuals, according to the state and developement of the lungs, and

* Annals of Philosophy, Sept. 1823.

according to the particular circumstances of the individual at the time of the experiment.

The influence which the state of the individual exerts upon the function was first shewn by the experiments of Dr. Prout and Dr. Fyfe. They proved that the carbonic acid gas formed during respiration is liable to be very materially affected in its quantity in the same individual, by various circumstances. It was formed in a minimum quantity during the night; and the maximum quantity, which was generally produced about noon, exceeded the minimum about one-fifth of the whole. The passions of the mind were found to have a great influence over its production; the depressing passions diminishing its quantity, and those of an opposite nature the reverse; exercise, when moderate, appeared to increase in some measure the quantity, but fatigue diminished it. The greatest decrease experienced was from the use of alcohol and vinous liquors, especially when they were taken upon an empty stomach. In short, whatever diminished the powers of life, as low diet, mercurial irritation, &c. appeared, from the experiments of Dr. Prout and Dr. Fyfe, to have the effect of diminishing the quantity of the carbonic acid.

Dr. Crawford found the quantity of this gas was much diminished when respiration was performed in a high temperature; and Lavoisier and Seguin confirmed his observation. Nearly similar results to theirs were obtained from some experiments which we performed in 1815; and from the data thus obtained, we endeavoured* to account for several of the most important diseases to which the inhabitants of warm countries are liable. Similar experiments were afterwards performed in an intertropical climate, where we found the diminution of the quantity of carbonic acid to be considerably greater than that which our experiments in an artificial temperature of equal elevation had furnished. This seems to be accounted for by the depressing influence upon the nervous system which the atmosphere, loaded with moisture and malaria, may be reasonably expected to produce. We also attribute a share of this discrepancy to the increased function of the skin, which evidently co-operates in hot climates with the lungs, and performs a subordinate respiratory function. In some comparative experiments made by us on that occasion, both on our own respiration, and on the respiration of a negro having a chest of about equal capacity, we found that the quantity of carbonic acid formed during respiration, in a given time, was much greater in our case than in that of the negro; and that the carbonic acid formed upon the cutaneous surface of his body exceeded that formed on ours in about the proportion of 3 to 2. We shall not pursue this particular topic farther at this place, as we propose considering it more at length on a future occasion.

Reverting to the question, whether the carbonic acid is formed *within* the vessels or *without* them, — we must remark, that the evidence on the subject is very contradictory. The experiments of Dr. Edwards, already referred to, shew that the former process exists, at least to some extent; and it is farther supported by the fact, established by Berzelius, that blood, especially its colouring part, not only absorbs oxygen very quickly, but it also retains some part of the carbonic acid thereby produced, but whether or no this absorption will take place through the parietes of the capillaries, is the point at issue. The evidence for the absorption of oxygen through the capillary parietes, is, however, nearly on a par with that for the excretion of the carbon; if the vessels will permit the transmission of the one, they may allow the transit of the other.

Those who contend for the passage of the carbon from the vessels, and who, consequently, consider that the carbonic acid is formed externally as respects the vessels, support their opinion by the experiments of Mr. Ellis, who first promulgated the doctrine. His experiments were, however, performed out of the body, and under circumstances which entirely excluded the operation of the vital influence of the lungs, and of the system generally.

The most conclusive experiments in favour of this opinion are those performed by MM. Magendie and Orfila. They found that phosphorus, dissolved in oil, and injected into the jugular vein of a dog, was expelled by the mouth and nostrils in the form of copious vapours of phosphorous acid; which could hardly have been the case if the phosphorous acid had been formed within the vessels, as in this case it would have remained in solution in the blood, it not being a volatile substance. It might, therefore, be supposed that the phosphorus was excreted in a state of minute division from the vessels of the lungs, and meeting in this state with the oxygen of the atmosphere, formed the phosphorous acid in question. If this reasoning be admitted with respect to phosphorus, it may be extended to the carbon contained in the venous blood.

From the contradictory evidence on the subject; from the nature of that evidence; from the experiments of Dr. Edwards; from various analogies that might be adduced, could our limits permit, from the conformation of the lungs, and the extent of their excreting and absorbing functions, as evinced by experiments; and lastly, from the consideration that, although respiration takes place frequently, yet a very large portion of air remains for a considerable time in the chest, thereby allowing the vitality of the lungs themselves to be exerted upon the air contained in them, — we conclude that this organ may act in both the ways contended for; and that, whether it act in one manner or the other, more or less partially, the process is a vital one, and whatever chemical laws may be employed in it are under the control of the vital influence of the organ, and modified by the ever-varying condition of this influence.

II. *Of the absorption, and exhalation of azote during respiration.* — Another subject of much interest, connected with the respiratory function, is that which immediately relates to the absorption in the lungs of a portion of the azote contained in the respired air. On this point, also, the results of experiments have been various, and opinions respecting them equally so. Dr. Edwards, of Paris, who is well known as a very able and intelligent physiologist, concludes, from different experiments, and from the circumstance of the opposite results which they give, — some indicating a diminution of the azote of the air, others an increase of it during respiration, — that this gas is absorbed into

* These views were contained in a Latin thesis written at Edinburgh in 1815.

the circulation, and afterwards discharged from it; and that each of these actions is regulated by the constitution, habit, and circumstances of the individual, and by the influences to which he may be subjected; the absorption being to a small extent, while the exhalation is considerable, and *vice versâ*.

Independently of the satisfactory nature of the experiments whence Dr. Edwards has drawn his inferences, there are many collateral proofs that may be brought to their support, derived from the manifestations of the animal economy in health and in disease; and we have little doubt, that not only azote, but that other gases, even those whose presence in the respired air are accidental, may be also absorbed into, and discharged from, the circulation, in a greater or less quantity, according to the varying state of the vital energies of the system.

III. *Of pulmonary transpiration.*—The mucous membrane of the lungs gives off a considerable portion of the watery secretion, which is carried out of the lungs, in the form of vapour, by the respired air. This perspiration equally takes place when the animal breathes a gas containing neither oxygen, hydrogen, nor azote; it therefore does not result from the combination in the lungs of the hydrogen contained in the blood with the respired air; but is strictly an aqueous vapour, slightly charged with animal matter, and is the production of a vital transpiration or secretion.

It has not been determined whether or no it be produced from the bronchial or from the pulmonary arteries. The question is difficult to decide, as an injection thrown into either set of arteries arrives on the surface of the air-cells. Pulmonary transpiration may contain, like secretions, foreign matters which have been conveyed into the circulation; the lungs acting as an organ eliminating them from the system. This has been shewn by some experiments of M. Magendie; and also in experiments which we performed, especially one, in which ten drachms of the oil of turpentine were chiefly discharged by the lungs from the circulation in the state of vapour, within twenty-four hours.* The large quantity of the turpentine vapour evolved from the lungs on that occasion, leads us to suppose that transpiration takes place principally from the venous blood, about the time when the changes are effected in it by respiration. This experiment also seems to support the doctrine of the evolution of carbon from the blood.

IV. *Of the assimilating function of the lungs.*—The extent of the function of the lungs has been a matter of doubt. Their principal office, namely, that of changing venous into arterial blood, has always been admitted, although the nature of the process has been disputed. Many physiologists have, in addition to this, attributed to them an assimilating influence which is exerted chiefly upon the absorbed chyle and lymph which the venous blood contains. This opinion appears correct. But the process is purely a vital one. If the opinion of Dr. Edwards respecting the absorption and exhalation of azote be correct, this substance may be instrumental in the process.

A third function has been referred to this organ, viz. the formation of animal heat. But however intimately related it may be with the respiratory process, it cannot be considered a function of the lungs. It must, nevertheless, be allowed, that the changes induced upon the blood during respiration are preparatory to the evolution of animal heat; and although we contend that this heat is immediately the result of a manifestation of the vital influence of the ganglial system of nerves, exerted upon the blood contained in the vessels to which these nerves are distributed, yet it must be admitted, that the respiratory processes are necessary to its production, inasmuch as they produce on the blood a change of properties, which are requisite to excite this system, and as this fluid, when thus changed, contains the materials necessary to, or is otherwise in a suitable condition for, the manifestation of the influence which that part of this system of nerves that is distributed to the blood-vessels exerts.

OF THE PRODUCTION OF ANIMAL HEAT.

(Note Y. See pp. 155, 158.)

It is not necessary to add at this place much to what is contained in the text, and to what we have said at page 15, and towards the conclusion of the preceding note. It will there be perceived that we have attributed the production of animal heat to the vital influence exerted by that part of the ganglial system distributed to the arteries on the blood which they circulate.

Preparatory changes, however, take place in the lungs, which are necessary to the exertion of this influence, and to the evolution of heat; but as it was contended that those changes are more of a vital than of a chemical nature, so it is considered that the production of heat is more the result of the influence which the soft nerves supplying the vessels exert upon the blood, than of the change in the capacity for caloric which the blood itself experiences in its passage into the venous state. The difference of capacity which actually exists between venous and arterial blood is not sufficient, according to the experiments of Dr. Davy, to form the basis of the chemical theory formerly received; but the difference which actually does exist may be concerned in a subordinate manner in the process.

Conformably with the opinion that was first maintained on an occasion already alluded to, page 15, we infer that the various causes which modify the production of animal heat act, 1st, immediately upon the organic system of nerves themselves, changing the condition of their influence; 2d, upon the blood, altering the nature and composition of this fluid, and thereby rendering it unfit for producing the requisite excitement of this system of nerves, and less capable of the changes which the influence of these nerves produces upon its constituent parts; 3d, immediately through the cerebro-spinal system, modifying the influence which this system imparts to the ganglial.

These different ways in which the vital influence, exerted by this system of nerves in the production of animal heat, is modified, might have been illustrated by the results of experiments, and by reference to facts in comparative physiology and in pathology, if we could have admitted of so great an extension of our limits.

* For the particulars of these experiments, see the Medical and Physical Journal, vol. xlvi.

From what we have said, it will be perceived, that we view the production of animal heat more in the light of a vital secretion than of a chemical phenomenon; and that, like the other secretions and nutrition, it proceeds from, or is controlled by, the vital influence of the ganglial system of nerves, and is co-ordinate with the vital manifestations of the whole body.

OF THE CUTANEOUS FUNCTION.

(NOTES Z. See p. 169.)

I. *Cutaneous exhalation, or insensible transpiration.*—In transpiration there appears to be two actions,—a physical one, consisting of the evaporation in the air of the fluid parts of the body; and a vital action, giving rise to an excrementitial exhalation, of which the skin is the organ. This view of the subject is justly contended for by Dr. Edwards; but we think he has refined in an unnecessary manner in explaining it. The cutaneous exhalation is doubtless an organic function, of which the skin is the organ; but we conceive that the skin must first perform its office before the physical action can take place to any considerable extent: in short, that as transpiration is performed, the physical law, evaporation, operates, and that both go on, the latter as a consequence of the former, *pari passu*, until an increase of the transpiration on the one hand, and an uncommonly dry state of the atmosphere on the other, give us different results. When the former takes place, we perceive the formation of sweat, or the transpiration becomes sensible: when the latter exists, then the phenomenon for which Dr. Edwards and some others have argued, as constituting one of the actions into which this function may be divided, really supervenes to some extent. Thus we have witnessed, during the Harmattan wind, which occasionally blows on the west coast of Africa, and which is remarkable for its dryness, evaporation going on so rapidly as to give rise to very inconvenient sensations, and even to serious disorders of the parts which are usually exposed to the air. In this case the evaporation exceeds the mere solution of the transpired fluid in the surrounding atmosphere; and the parts of the body which are subjected to its operation have a portion of the fluids sent to the surface carried off by it, in addition to what is exhaled by the natural and organic action of the vessels of the skin.

The cutaneous exhalation contains a portion of the carbonic and lactic acids, and sometimes minute portions of urea and uric acid; and, according to our experiments, these are more abundant in negroes and the dark-skinned races than in Europeans.

II. *Of the sweat, or sensible exhalation.*—When we said that, if the production of the halitus, or insensible transpiration from the skin, exceed the evaporation of it in the atmosphere, sweat is formed, we stated the source of this fluid. It is, therefore, produced from the same vessels as the insensible perspiration. But although this is the case with respect to their source, there is some difference between the nature or chemical constitution of the sensible and insensible cutaneous exhalations. The former is generally less charged with carbonic acid than the latter, but it abounds more with the salts usually excreted from the system.

A careful view of the functions of the skin throughout the different classes of animals leads us to conclude, that it performs operations which hold an intermediate place between those of respiration and elimination,—that it partakes of the character of a respiratory and of an eliminating organ.

1. *It is a respiratory organ.*—This is shewn by the circumstance of this function being performed in the lowest orders of animals on the external surface of their bodies only; by the developement of the organs of respiration in the different orders; and by the gradual perfection at which the respiratory organ arrives in ascending the scale of animal creation. In the higher animals the respiratory apparatus becomes more and more distinct, and the function depending upon it more and more limited to appropriate organs; however, the same type which characterises the lower orders, and is most remarkable in them, is still preserved throughout the whole series of the animal scale, although it becomes gradually, and nearly, but not altogether, lost. Thus in man the lungs perform the chief respiratory process; but, even in him, the respiratory function of the skin is remarkable. Carbonic acid gas is produced from the cutaneous surface, transpiration also takes place there; and this respiratory act of the skin becomes more and more remarkable under circumstances which diminish or partially obstruct the respiratory process of the lungs. Thus we found that the quantity of carbonic acid gas formed in the lungs in a given time, and in the same individual, was about one-third less in a hot climate than in a cold one; this was about the average result of our experiments: whilst we observed that the respiratory function of the skin, both as respects the quantity of the insensible transpiration and the formation of carbonic gas, was very remarkably increased.* In a negro, as far as we could infer from experiments performed on a single limb, the respiratory function of the external surface of the body was much greater, and the quantity of carbonic acid formed in his lungs much less, than in our own case, although our size and weight were equal. Hence we were led to infer, that in this race of the human species the skin performs a much greater supplementary function to that of the lungs, than in the inhabitants of cold or temperate climates.

In two cases that came under our observation, in which the lungs were partly destroyed from an imposthume, and the side of the chest was consequently contracted, the cutaneous functions were afterwards very remarkably increased. Were it consistent with the limits of these notes, many facts illustrative of this particular function of the skin, as it respects the inhabitants of cold, temperate, and hot climates, might be adduced.

2. *The skin is an eliminating organ.*—M. Richerand has so fully illustrated this function of the skin, and contrasted it with that performed by the kidneys, that it is unnecessary to say any thing respecting it at this place. The che-

* The experiments which were made in order to ascertain this, from the want of the means and proper facilities, were not performed upon the whole body,—they were made only upon a single limb; but the results were very decisive and remarkable.

mical analysis of the perspired fluid, given in the next chapter of the *Appendix*, will shew to what extent it performs an eliminating office.

OF THE FLUIDS.

(NOTES A A. See pp. 170—183.)

In addition to the classifications of the fluids, noticed in the Note at page 232, we may mention that adopted by M. Chaussier. He divides the fluids into five classes: those produced by the digestive process, the chyme and the chyle; the circulating fluids, the lymph and the blood; the exhaled or perspired humours; the follicular humours; and the glandular humours.

M. Adelon,* the able and eminent pupil of M. Chaussier, has proposed another classification, which possesses some advantages over those which have preceded it. It is also simpler and more natural. He divides the organic fluids into those of *absorption*, the fluid *specially nutritive*, and *the secreted humours*.

1. *The absorbed fluids* are the chyle, the lymph, and the venous blood. These are taken up and conveyed by the lymphatic and venous class of vessels, and ultimately become assimilated with, and indeed concur to form the fluid specifically nutritive. Thus the chyle, after a longer or shorter course, mingles with the lymph, both are poured into the venous blood, and when they arrive at the organs of respiration, they become perfectly united, being converted into the nutritive fluid by the functions of those organs.

2. *The fluid especially nutritive.*—The three fluids constituting the first class being changed in the respiratory organs into that which can alone nourish the body, thus constitute the second class, which, in its turn, furnishes the materials of all those embraced by the third. The second class is, therefore, the arterial blood only, which, being fully perfected in the lungs by the action of the atmospheric air, and circirculated throughout the body, furnishes the materials of nutrition and secretion, and stimulates and contributes to preserve the functions of the living solids, and, in conjunction with these solids,† produces the calorification of the animal system.

3. *The secreted humours.*—This class may be divided into three orders, according to the forms of the secreting organs which produce them; namely, into *exhaled* or *perspired fluids*, *follicular humours*, and *glandular humours*.

A. *Exhaled* or *perspired humours.*—These are numerous, are produced in the form of vapour, and they differ from one another in their physical and chemical properties, and in the purposes which they fulfil in the animal economy. They are, moreover, distinguished into those which are taken up by lymphatic or venous absorption, and carried back into the torrent of the circulation, and into those which are entirely thrown out of the body; the former being usually denominated *recrementitial*, the latter *excrementitial*, from these circumstances.

The recrementitial fluids are all produced in cavities or in situations that have no external outlet. The following enumeration includes all the fluids appertaining to this genus:—1. *Serous* fluids, as those which are exhaled on the surface of the arachnoid, of the pleura, of the pericardium, the peritonæum, and the tunica vaginalis.—2. The *synovia*.—3. The *serosity of luminous tissues*.—4. The *fat* formed in the adipose tissue.—5. The *marrow*, or medullary juice.—6. The *colouring humour of the skin*, placed under the epidermis.—7. The *colouring humours* of the iris, of the uvea, and of the choroid.—8. The *three humours of the eye*—the aqueous, crystalline, and vitreous.—9, The *lymph of Cotugno*.—10. The *humour of the lymphatic glands*, a gelatino-albuminous fluid, existing in the spongy tissue of these organs.—11. and lastly, the *fluid perspired* on the internal surface of all the vessels, the existence of which may be doubted, as it is next to impossible to demonstrate its existence. In addition to the perspired recrementitial fluids, may be added those which exist in the human ovum, viz. the *amniotic fluid*, the *water of the chorion*, which exists between the chorion and amnios only during the early months of pregnancy; and the *water of the umbilical vesicle*, which may be compared to the yolk of an egg, and which some physiologists believe destined to nourish the embryo before the developement of the placenta.

The excrementitial perspired fluids are all thrown off from the external surface of the body, and from the mucous membranes, which have a communication externally by means of the natural outlets, and which may therefore be considered as merely forming parts of the external surface.—1. *Those fluids which perspire from the skin*, as the cutaneous insensible perspiration, and the humour constituting the sweat.—2. The *fluids perspired from the respiratory apparatus;* these differ somewhat in different situations, as in the nasal cavities, in the trachea, and bronchia.—3. The *humours exhaled on the surface of the digestive canal*.—4. Those *humours exhaled on the internal surface of the urinary apparatus*, viz. on the internal surface of the ureters, the bladder, and urethra.—5. The *fluids exhaled from the genital organs*, namely, from the internal surface of the vesiculæ seminales and ejaculatory conduits, in the male, and from the uterus and vagina in females (the menstrual flux and the lochia).

B. *The secreted follicular fluids* are those formed by a particular secreting organ called follicular. They are all excrementitial, and consequently are formed on, and eliminated from, the two external surfaces of the body, the skin and mucous membranes. They consist of,—1. The *sebaceous humour of the skin*.—2. The *cerumen;* the *humours of Meibomius*.—3. The *humour* of the caruncula lachrymalis.—4. The *humour* secreted at the base of the glans penis in the male, and on the surface of the vulva in the female. The humours secreted by the follicles in the mucous surfaces are generally characterised by the generic term *mucus*. They are distinguished into the *mucus of the respiratory organs*, the *mucus of the digestive apparatus*, of *the urinary apparatus*, and of the *genital organs*. The *humours formed by the prostate*, and by *the glands of Cowper*, compound and glandiform follicles, are usually referred to the last mentioned in this enumeration. The fluid secreted by the tonsils is generally classed with those of the digestive organs.

* *Physiologie de l' Homme*, par N. P. Adelon, D. M. P. &c. vol. i.

† By living solids is here meant all sensitive and irritable parts,—all those which are influenced by an irritating cause.

C. Lastly—The *secreted glandular humours* are the production of glandular organs. They are,—1. The *lachrymal fluid.*—2. The *salivary fluid.*—3. The *pancreatic humours.*—4. The *bile.* —5. The *urine.*—6. The *semen* ; and 7. The milk.

It may be remarked generally, with respect to the humours, that the degrees of fluidity which belong to them vary greatly from a state of gas or of vapour to that of semi-fluidity ; they have, moreover, all the physical conditions constituting a fluid body. Their fluidity, however, does not result from the general forces of matter, but from those of life. Indeed, the vital influence modifies their physical form of existence, in a more or less marked manner, as long as they continue subjected to its operation. From this source also they are imbued with a certain influence, the presence of which is indicated by the continuance, for a time, of the specific characters of each. This influence, being no longer renewed when they are removed from the body, soon becomes dissipated, and the secretion which, while within the sphere of the animal system, and for a short time afterwards, possessed an emanation of the vital influence sufficient to give it certain characters, and to preserve it from the chemical changes to which its constituents are naturally prone, at last falls into a state of dissolution, as unequivocal as that evinced by the textures of the body. In confirmation of this view, we need only refer the physiologist and pathologist to the comparative condition of the more perfectly elaborated secretions immediately after their formation and excretion, and after periods of various duration have elapsed from the time of their discharge from the body.

Finally, we may remark, that the fluids, being composed of molecules moving with facility on each other, cannot, as the solids, be traced to constituents of an elementary nature. They can only become the subject of microscopic research in our endeavours to trace the nature of their constitution ; by this means we can merely learn that they are generally composed of globules, swimming in a fluid substance ; and whatever be the fluid employed, we perceive only globules suspended in an amorphous liquid. It should, however, be remarked, that, as we find in some solids merely a concrete amorphous substance containing no globules,—as in the cellular tissue for example, —so we perceive some fluids destitute of globules, and formed only of an amorphous substance, which is perfectly fluid. In other solids and fluids, on the contrary, we find both globules and an amorphous matter, which is concrete in the former, and liquid in the other. But these globules vary greatly, both in solids and in fluids, and even in the same part, according to age : those of the blood, for instance, are composed of a solid central part, and of an external envelope which is coloured ; those of the chyle appear to be the same as the central part of the former, without its coloured envelope ; those of the muscular fibre seem to be the same as those of the blood ; those of the brain and nerves are smaller than the foregoing ; and those of the kidneys are smaller than those of the spleen. During the first epoch of *conception*, the globules are not visible ; they, however, soon form and become more and more distinct.*

OF THE BLOOD.

(NOTES B B. See pp. 171—177.)

I. *Of the small or colourless globules of the blood.*—The researches of Sir Everard Home and Mr. Bauer† seem to lead to the following conclusions respecting these globules.

1. That the milk-like fluid, the produce of digestion (chyle), which is found in the lacteal vessels and glands, contains an infinite number of white globules, chiefly of a minute size.

2. These newly discovered minute globules are $\frac{1}{2800}$ part of an inch in diameter.

3. That the chyle contains also some white globules, of the size of the red globules of the blood.

4. Mr. Bauer supposes that the full-sized globules acquire their form in the lacteal glands.

5. Sir Everard Home considers that the globules of the blood receive their red hue in the vessels of the lungs.

6. That lymph or fibrine, whether taken from an inflamed surface, from the buff of what is commonly called inflamed blood, or from the slowly formed layers of aneurismal tumours, consists of innumerable white globules, much smaller than those which constitute the red globules of the blood, and similar to those minute globules already described.

7. That those small globules constitute the substance thrown out in inflammation.

8. That they are held in solution in the serum, and consequently are only brought into view in the act of coagulation.

9. That these globules, as well as those which subsequently receive the red colour, are the produce of digestion, and are formed in the pyloric portion of the stomach and in the duodenum, surrounded by a glairy mucus, which is met with in these parts.

MM. Prevost and Dumas‡ agree with Sir

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* See on this subject *Physiologie de l'Homme*, par N. P. Adelon, vol. i. p. 116.

† Phil. Trans. for 1820.

‡ The microscopic observation of the blood satisfied these gentlemen that this liquid, during life, was nothing else than the serum, holding in suspension small, regular, and insoluble corpuscles. Those are uniformly composed of a central, colourless spheroid, and of a species of membranous bag, of a red colour, surrounding this spheroid, from which it is easily separable after death. The central body is white, transparent, of a spherical form in animals with circular particles, of an ovoid form in those with elliptical particles. Its diameter is constant in the first, but it varies very perceptibly in the second. It manifests also a great disposition to assume aggregates or ranges, in the form of a string of beads.

The coloured portion appears to be a kind of jelly, easily divisible, but insoluble in water, from which it may always be separated by repose. It is likewise transparent, but much less so than the central corpuscle ; and the fragments arising from its division are not susceptible of regular aggregation. As the attraction, which keeps the red substance fixed round the white globules, ceases at the same time with the movement of the liquid, these globules can then obey the force which tends to unite them, and to form a net-work, in whose meshes the liberated red colouring matter gets enclosed, and thus

Everard Home as to the form and structure of the globules of the blood; but they do not admit with him that the red globules undergo a rapid change after they escape from the vessel, or that the colouring matter which envelopes the central spherical body separates from the globule so soon as thirty seconds after the blood has issued from the vein. They, however, agree with him in saying, that these central spheres (the smaller globules) unite themselves in filaments, which differ in no respect from the muscular fibre. They observed also small globules in the milk, in pus, and in the chyle; and they consider that those of the former fluids have been, and these of the latter are to be, surrounded by the colouring matter of the blood.

MM. Prevost and Dumas found the globules of the blood to be circular in all the mammalia; and in their size to vary in different animals: they are smallest in the goat.

The globules are elliptical in birds, and they vary considerably in size in this class of animals. This variation is chiefly in the great axis of the globules. They are elliptical also in all cold-blooded animals.

II. *Of the coagulation of the blood, and on its vitality.*—On the part of the subject before us we cannot enter minutely. We will merely state, as briefly as we can, those inferences at which we have arrived, after a careful examination of the phenomenon itself, under various circumstances, and of the different opinions entertained respecting it.

1. According to our own observations, as well as those of Treviranus and Kolk, whose researches on this subject have been extended and faithful, the particles or globules of the blood possess a rotatory motion during life, and this motion continues until the phenomenon of coagulation takes place.

2. We conceive that this motion of the globules is the cause of the blood's fluidity.

3. That the motion of the globules of the blood is the consequence of the vital influence emanating from the ganglial nerves distributed in the parietes of the vessels in which they circulate, and endowing them with vitality. (See pp. 14, 15.)

4. We therefore infer that the blood possesses vital properties, but that these properties are *derived* from, and depending upon, the vital conditions of the vessels in which, and the organs through which, it circulates; that it is not the *source* of vitality, although manifesting a reciprocative vital influence; and the manifestations of vital properties may be traced in the chyle, or originate there, proceeding from the admixture of the secretions contributing to its formation, and from the vessels and organs through which it circulates in its course into the current of the blood,—vitality thus beginning to manifest itself, in its lowest grades, with the formation, in the chyle, of the central globules of the blood.

5. That the cause of the coagulation of the blood is not to be found in external agencies, but in the loss of that emanation (proceeding from the organic nerves distributed to the coats of the vessels) of the vital influence with which the globules are endowed.

6. That the presence of the air, especially of the oxygenous portion of it, promotes this phenomenon.

7. That when coagulation commences at any point of a mass of blood, it is rapidly propagated throughout the whole: this may arise from the cause being co-ordinate, or nearly so, throughout the whole.

8. Neither the heat of the body, nor the strength of the circulation, are causes of the blood's fluidity: they are both results of the same cause, viz. the vital energy of the vessels, and vital endowment of the globules of the blood; both are co-ordinate, and both, as well as the phenomena of coagulation, are dependent on this source.

9. That coagulation occurs sooner in venous than in arterial blood; and that coagulation of arterial blood is still longer delayed if it be prevented from leaving the arteries.

10. That coagulation takes place the sooner after the blood is removed from the vital sphere of the system, the weaker the vital energy to which it was subjected whilst circulating in the system.

11. That the weaker the vital energy, and, consequently, the quicker the coagulation, the more lax is the coagulum which is formed.

12. That, on the same principle, coagulation is more slow, and the coagulum more firm, according as the vital influence of the vessels is more energetic.

13. That the quantity of globules modifies these results; a large proportion also of these globules indicates great energy, and *vice versâ*.

14. That, as the central globules retain their coloured envelopes during their circulation in the blood-vessels, and lose them soon after removal beyond the sphere of the vital influence of these vessels, and as this is a part, and indeed the first part, of the act of coagulation, so we consider that it is in consequence of the vitality emanating from the interior of the vessels into the blood, that the coloured envelopes of the central globules continue to surround them; and, consequently, that the separation of

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to produce the phenomenon of coagulation. If the coagulum be exposed to a stream of water, the colouring matter is washed away, while the aggregate formed by the white globules remains in the form of filaments, in which may be recognised, by means of the microscope, the aspect and structure of the muscular fibre.

Three animal substances ought, therefore, to fix our attention: these are, the albumen of the blood, the white globule, and the colouring matter which envelopes this. With respect to the colouring particles of the blood, these chemists suppose that it is formed of an animal substance in combination with a peroxide of iron. The colourless globules they considered to be coagulated albumen. They have examined the proportion which the white corpuscles and red matter together bear to the rest of the blood, in a great variety of animals; and they find them most abundant in birds, next in the mammalia, especially the carnivorous mammalia; and they are least plentiful in cold-blooded animals. In man they constitute about one hundred and twenty-nine parts by weight per thousand. They are more abundant in arterial than in venous blood; one thousand parts of the arterial blood of the sheep, dog, and cat, contain ten parts more of these particles than blood taken from the veins. The serum is identical in both

the envelope from the central globule is the result of the loss of the chief portion of that vitality which proceeds from the containing blood-vessels; and as this loss of vitality may be reasonably supposed to be quickest where it has been originally the least, therefore the separation of the envelopes and the coagulation will be the quicker, the weaker the vital energy, and *vice versâ;* and the coagulum will be the more lax.

15. That the loss of the vitality emanating from the vessels, and consequently the loss of their envelopes, disposes the central globules to attract each other; and that in the exertion of this contraction they dispose themselves into reticulated fibres, which entangle the colouring matter and a portion of the serum, and thus the clot is formed.

16. It would appear that the central globules continue to retain, in the fibres which they form in the act of coagulation, a small portion of the vital emanation with which they were endowed; inasmuch as the fibrous part of the coagulum evinces phenomena approaching to those denominated irritable; and that it is the loss of the chief part of the vitality, and not the whole of it, which occasions the separation of the coloured envelopes from the central globules.

17. That the firmness of the coagulum, and the irritable phenomena evinced by its fibrous part, are proportionate in degree to the vital energies with which the vessels are endowed by the ganglial nerves distributed in them, and to the emanation which the globules themselves derive from this source.

18. That the vital emanation, proceeding from the ganglial nerves distributed in the vessels, affecting the globules in this manner, and giving rise to these phenomena, has been the cause of, and has countenanced, the hypothesis of the vitality of the blood, — a vitality which does not belong to it independently of these nerves, and of the vessels and organs through which it circulates, which it possesses in a diminished degree, and which is an emanation from a different source (Prop. 3), which source is efficient in the formation of the blood itself, and bestows on it, through the medium of the vessels containing it, the chief properties which this fluid evinces in health and in disease.—(See Prop. 4, p. 49.)

19. That when the vitality of the system, especially that of the blood-vessels, is greatly diminished, as in purpura hæmorrhagica, scurvy, and in other diseases, coagulation either does not at all take place, or it takes place very quickly, and the coagulum is weak, lax, and resembling cruor. Under such circumstances, the envelopes separate rapidly from the central globules, because the vitality of the vessels is scarcely sufficient to continue them in connexion even when circulating through the vessels themselves; coagulation takes place quickly, because the motion impressed upon the globules by the vital energy of the vessels, owing to the defect of this energy, is soon lost, and because the separation of the envelopes from the globules takes place almost instantly; and the coagulum which is formed is weak, or it does not form at all, because the vitality of the globules is insufficient to dispose to an energetic attraction, or even to any attraction between the central globules.

20. In various diseases, especially in those which are malignant and infectious, when the vitality of the system is much exhausted, as in the advanced stages of typhoid and adynamic fevers, in the true infectious puerperal fever, and puerperal mania, in the worst forms of erysipelas and diffusive inflammation of the cellular structures, and in several other diseases, particularly when epidemic, or occurring in hospitals, the air of which is vitiated by crowding of the sick, and the decomposition of the discharges and secretions, as in lying-in hospitals, —the blood taken from a vein will often not separate into a distinct coagulum and serous fluid, but will assume the appearance of a straw-coloured gelly, at the bottom of which gelly the red envelopes of the vessels will be found forming a loose, reddish brown or blackisk stratum. In such cases, the blood, participating in the deficiency of the vital energy of the body, and being also, perhaps, deranged from the admixture of hurtful materials with it, which are not duly eliminated by the various emunctories, evinces the lowest grades of vital endowment; the attraction between the globules of the blood being so weak as not to give rise to the exclusion of the watery parts, and permiting the envelopes of the globules to separate speedily, and to form a loose and unadhering stratum over the bottom of the vessel.*

21. Opposite phenomena to the above, result from the increased energy of the vital functions generally, particularly of the vascular system, and of the functions of the nerves which supply it.

22. If this were a suitable place, various other morbid states of the blood, arising both from deficient vital energy and consequent inactivity of the functions of those organs which are the emunctories of the vascular system, and from the introduction of hurtful emanations and ingredients into the circulation, and occurring in the course of numerous diseases, especially such as are epidemic and febrile, might be adduced.

23. We may infer as a corollary, that the appearances which the blood exhibits have always an intimate relation to the vital conditions of the system, and to the state of excitement which the heart and blood-vessels present; and that the buffy coat is merely one of the manifestations furnished by the blood, indicating reaction of the powers of life, or excitement of the vascular system. We believe that the blood participates in the vitality of the body through the medium of the vessels and organs in which it circulates; that according to the degree or condition of this vital endowment, coagulation and the coagulum are modified in their phenomena and appearances, and the production of the buffy coat promoted or altogether prevented; and that the blood gradually acquires its vital endowment from the time that the secretions mix with the more soluble portions of the chyme and form the nutritious chyle, which also gene-

* This appearance of the blood has generally been observed by us in cases of disease characterised by unusual frequency of the heart's contractions, accompanied by great loss of vascular tone, and vital resistance of the system generally. The blood-letting in such cases has always been very hurtful.

rally presents the phenomena of coagulation, although in a less degree.

III. *Of transfusion of blood, and injection of foreign matters into it.* — MM. Prevost and Dumas* found that, after bleeding an animal until all organic actions ceased, and injecting, within a few minutes afterwards; the warm blood taken from another of the same species, until a quantity equal to that taken away was restored, the animal gradually revived and took nourishment, and perfectly recovered if the operation was well performed.

If, however, the blood injected was taken from an animal of a different species, possessing globules of the same form, but different in dimensions, the animal was very imperfectly revived, and could be rarely preserved beyond six days. The pulse became in these frequent, the temperature fell remarkably, if not artificially preserved, while the respiration retained its natural frequency. Immediately after the operation the dejections became mucous and bloody, and preserved that character until death.

If blood with circular globules was injected into the veins of a bird, the animal generally died, before the operation was completed, in very violent and rapid nervous convulsions.

Transfusion of blood from the cow or sheep into the veins of the cat or rabbit, was followed by the recovery of the animal in a number of cases.

The blood of the sheep excited in the mallard duck the most violent and rapid convulsions, which were immediately followed by death, as was observed to follow the injection of the first syringeful in land-birds.†

OF SECRETION AND EXHALATION.

(Notes CC. See pp. 180—187.)

Opinions have been various respecting the mechanism provided for the performance of exhalation and secretion. One class of physiologists contends for a separate order of very minute capillaries, proceeding from those carrying red blood, which they call exhalent or secretory capillaries, and devoted to these functions, (see p. 39.) Belonging to this class we may reckon Haller, Hewson, Sœmmering, Bichât, Chaussier, Alard, &c. As these vessels cannot be demonstrated, their existence is denied by Mascagni, Prochaska, Richerand, Magendie, and others, who argue, that these functions take place in the sanguineous capillaries, through the medium of organic lateral pores. The fact appears to be, that the evidence for a separate set of capillaries is equal to that for the existence of organic pores in the capillaries carrying red blood; it is not easy to demonstrate the presence of either; whilst both the one and the other may prove a sufficient medium through which the processes will go on, under the influence with which the capillary vessels are endowed. The existence and efficacy of this influence is sufficiently manifest, although the more minute instruments, by means of which it operates, cannot be satisfactorily demonstrated to our senses.

In respect of secretion, the state of opinions and of our knowledge as to the *manner* in which it takes place, or rather the mechanism provided for its performance, is similar to what we have shewn to exist on the subject of absorption and on that of the minute capillaries. In stating the opinions on these subjects, and those lately espoused by M. Alard, we gave the views of those who contend for the existence of minute lymphatics running into the venous capillaries, in a similar manner to that in which exhalent vessels are supposed, as stated above, to proceed from the arterial capillaries. But the latter set of vessels has been as little seen as the former. This, however, in a matter of this nature, is not a sufficient proof against their existence. Some physiologists, on the other hand, contend that exhalation and secretion take place through means of pores analogous to those which are supposed to be instrumental in the phenomena of absorption; and that the process is entirely one of transudation. But the same objection may be offered against the existence of pores as to that of the exhalents or secreting capillaries in question.

We believe that the precise way in which exhalation and secretion take place cannot be readily demonstrated to the senses, — that the one apparatus may explain the process as well as the other,—that secretion as well as absorption are not mechanical processes, although there are apparatuses, or subordinate instruments, provided for their performance,— and that they are essentially vital operations, and under the control of the vital influence with which the capillaries themselves, and the organs to which they belong, are endowed.

As to the question of pores, it must be granted, that the solids of the body, and the parietes of the vessels, are all porous; it is only with respect to the extent and magnitude of the pores that the question can be entertained. Those who contend for the existence of separate and subordinate sets of capillary vessels, cannot deny the existence of pores; for if they do not exist both on the surfaces and in the textures whence these capillaries are supposed to originate, how could they obtain the fluids circulating in them? On the other hand, those who contend for the existence and functions of pores, cannot deny the existence of minute absorbents

* *Bibliothèque Univers. Juillet* 1821.

† Since MM. Prevost and Dumas have thus recalled the attention of the profession to the subject of transfusion, the operation has been performed successfully by Dr. Blundell and others in this country, in cases of excessive uterine hæmorrhage; and under favourable circumstances it promises to be of decided utility.

The experiments and observations of various physiologists and pathologists have also shewn that much advantage will be obtained, and a more energetic effect produced, by injecting immediately into the current of the circulation various medicinal substances, than when such substances are exhibited in the usual way. The results of this mode of treatment shew that a large proportion of medicinal agents act in a similar manner when injected into the blood, as when exhibited through the medium of the digestive organs — the quantity, however, in the former case requiring to be much smaller; and, moreover, it has been shewn also, that when active substances are thus introduced at once into the blood, they produce the specific effects usually observed to proceed from their use in the common modes of exhibition

or lymphatics; for they can be demonstrated to a certain extent as respects the minuter ramifications, and in a satisfactory manner as regards the more considerable branches. It appears to us that both species of organisation exist to a greater or less extent in different textures and secreting organs.

We refer our readers to our notes at p. 183, for some remarks on the fact, that each secreting viscus is supplied with a distinct ganglion, plexus, or both; that these preside over the secreting function; and that the functions of some of these ganglia are influenced by the operations of the cerebro-spinal system; as, for example, the secretion of the lachrymal gland is increased by the influence which the nerves of this latter system convey to the ganglion that supplies it, and is the chief source of its functions.

OF NUTRITION.

(Notes DD. See pp. 189—192; and Note S, p. 39.)

As we have already seen, in the Notes on the Capillary System and on Secretion, the function of nutrition has been explained by one class of physiologists by supposing the existence of nutritive capillaries, and by another by means of organic pores, with which they endow the capillary vessels circulating red blood, and to which they commit the exhalent, secreting, and nutritive functions. The first of these hypotheses supposes that nutrition takes place in minute colourless vessels, which proceed in a more or less tortuous direction from the arterial capillaries, absorption proceeding through the medium of a similar set of colourless vessels continuous with the former, which run into the venous capillaries, and thus the nutritious molecules are always circulating within colourless capillaries, which, with the nerves and larger capillaries, constitute the basis of the different textures.

Mascagni supposes that the arterial capillaries, at the point where they change into veins, are provided with exhalent pores, both for the purposes of secretion and nutrition; and that there every where exists the orifices of minute absorbent vessels, commencing in the latter description of pores, in order to take up the nutritive molecules. The elementary tissues consist, in his opinion, of this particular class of absorbent vessels, which contain the molecules as long as they are a part of the textures, and which, by their union, form the most simple membranes.

These hypotheses do not differ very materially. Both contend for the existence of very fine capillaries, which attract the nutritive molecules, and contain them in a state of progressive circulation, as long as they form constituents of the textures; these molecules being afterwards carried onward in succession into the branches of the absorbent lymphatics and into the veins. In the first of these hypotheses, the nutritious particles are supposed to circulate in the finest of the vessels proceeding from the arterial capillaries; in the second, the process is ascribed to the most minute radicles of the absorbents; but both agree in considering the molecules constituting the mass of the textures to be contained in colourless vessels, and to be in a state of continual circulation.

The opinion of Bichât on this subject is somewhat different. According to him, each molecule of those constituting the textures of the body is placed between the orifices of two vessels: one, a nutritive exhalent orifice, which has deposited the molecule; the other a nutritive absorbent orifice, about to absorb it.

Prochaska, who conceives that the arterial capillaries are continued directly into veins, considers that nutrition takes place in consequence of the porosity of the capillaries, and of the general permeability of the substances constituting the mass of the structures. M. Richerand espouses a similar opinion; but he seems to allow an organic property to the pores which he ascribes to the capillary vessels.

Opinions respecting the mechanism of nutrition, or the manner in which it takes place, can only be theoretical. We have not the means of demonstrating the existence or non-existence of either the one or the other mode of organisation contended for: each may of itself be sufficient to explain the phenomenon, as far as respects the apparatus required for the process, but it is only the apparatus. The function itself is purely a vital one. It presents us with a continual motion, of a double nature—a continual attraction and decomposition of material molecules. In the most simple animals, as the polypus, these processes go forward without any previous preparatory function: the animal imbibes, in a direct manner, similar molecules of matter to those of which it is itself formed from the surrounding medium, and again exhales them in a manner equally direct. In these there are no vessels destined for the purpose of circulation and nutrition, yet they present the phenomenon of irritability; and on examination with a microscope, their structure appears almost homogeneous, with the exception of globules entirely similar to those which are observed in the ganglial nerves of the higher animals. As these are the chief marks of internal organisation which can be detected in the very lowest of the animal kingdom, and as we must conceive that the organisation must be instrumental in the nutrition and operations of animal bodies, and as, moreover, we perceive that the perfection of the organisation or material apparatus is commensurate with, and has an evident relation to, the extent of the vital operations which it performs, — so it seems reasonable to suppose that this organisation, which is the only one that is detected in the very lowest of animals, is the chief and indeed only instrument of the limited function which they perform; and that, as a similar but more perfect organisation presides over the nutritive function of the highest animals, so this presides over that of the lowest, without the assistance of the complicated capillary apparatus assigned by some physiologists to them; and if a distinct set of subordinate capillary vessels be not requisite to the nutritive function in the lowest class of animals, we may allow that this function takes place in the highest classes, under the dominion of the more perfect nervous organisation to which we have assigned it, without the existence of the complicated capillary apparatus for which some contend.

Concluding, therefore, that as the nervous globules demonstrable in the very lowest animals are the only internal organisation which they evince, that organisation must have a determinate object or function, which it performs under

the control of the vitality with which it is allied, and which all animals possess; and that nutrition and irritability are the only organic actions which these animals perform,—so it must inevitably follow, that these actions result from the vital influence allied to the particular organisation in question; and that the nervous globules constituting the only marks of internal organisation possessed by these animals, attract from the surrounding media, in consequence of the vitality with which the globules are endowed, these molecules of matter corresponding to those forming the structure of the animal, which come within the sphere of their influence, and retain them for an indefinite time, unassisted by either exhalent or absorbent vessels. Now, as the same type, especially as respects the nutritive functions, may be observed throughout the whole animal creation, and as we can trace nervous chords, formed of globules similar to those already ascribed to the lower, and indeed to all animals, throughout almost the whole of their bodies,—is it not reasonable to suppose that similar globules exist in all the simple textures in a more diffused form—that the globules constituting the organic or ganglial system of nerves become more disseminated amongst the molecules of the textures in the course of their distribution with the capillary vessels, and of their more direct ramifications and terminations in the textures themselves? If this be granted,—and it scarcely can be denied, for it has been demonstrated in different orders of animals—and as it has been shewn that these nervous globules are present, in a more or less organised form, throughout the whole animal creation—it may consequently be inferred, that the same function which we have ascribed to them in the lowest animals should be extended to them in the highest. This is conformable to the laws characterising the animal economy.

As we have contended in another place, (p. 13, *et seq.*) conformably with this opinion, that the ganglial nerves, in some one or other of their forms of existence, are present throughout every part of the body, that they preside over digestion, nutrition, secretion, &c. and are more nearly allied than any other texture with the vital influence which the body exhibits,—so we now conclude, that the globules constituting the ganglial system, being allied with vitality, and being distributed in different forms of connexion to the various textures of the body, exert, in consequence of the vital influence with which they are endowed, a vital attraction on those molecules of matter which come within the sphere of their influence; that the force of this attraction, and the manner in which the material molecules are arranged in order to form the different textures of the body, result in a great measure from the influence proceeding from the form, the number, or the condition of these globules in the textures which it is their office to perpetuate; and that the chief office of the digestive, the respiratory, the animalising, and the circulating processes, is to present the materials, whence the different textures are preserved and nourished in a fit state for the exertion of this vital attraction; and that the principal operation performed by the capillary vessels is to convey these materials within the sphere of this attraction; and, so that this is performed, it matters but little whether or no these vessels accomplish it by means of subordinate nutritive capillaries, destined to the circulation or deposition of the nutritious molecules, or by means of organic pores, with which their parietes may be provided.

But, whilst we suppose that the function of nutrition may thus take place in consequence of a vital attraction, resulting in the manner which we have explained, and exerted exterior to and independently of the vessels, and whilst we consider this explanation to be supported by the nutritive actions of the lowest animals; yet we would by no means exclude the influence of that part of the ganglial nerves distributed to the capillaries from a part in the operation, more especially in the higher classes of animals. Indeed, it seems difficult to suppose which of those in the higher animals—namely, whether the nervous globules distributed to the simple textures, and placed beyond the capillaries, or those constituting the nervous fibrilæ which surround them,—are most efficient in the nutritive process. An intimate view of the subject would suggest, that in man and the more perfect animals the latter organisation is the more active of the two in the operation in question; and that the capillary vessels, in consequence of the ultimate nervous structure which surrounds them, and of the vital influence which this structure exerts, secrete from the fluid circulating in them certain materials in a similar manner to that in which they perform the other secretions in secreting organs, and by means either of appropriate vessels or pores.

As it has been shewn that the blood consists of minute globules, or corpuscles, surrounded by a coloured envelope circulating in a mass of fluid, and that the simple solids of the body are constituted of similar corpuscles, in a state of intimate or vital attraction, to those of the blood, when they are separated from their envelopes,—so it may be inferred, that a part of the function, which the ultimate distribution of the ganglial nerves performs on the capillary vessels, is to secrete similar corpuscles, from the blood circulating in these vessels, to those of which the texture is formed in which the operation takes place; and that this having been accomplished, the vital attraction is preserved by means either of the influence with which these corpuscles are endowed, as a consequence of the previous process of animalisation which they have undergone, or of the influence exerted upon them after they leave the vessels by the nervous globules and fibrilæ disseminated in the textures, or perhaps by both species of vital action, either the one or the other acting more or less partially, according to the nature of the particular texture in which the process takes place, and according to inappreciable and fortuitous causes.

Hence it will be perceived that nutrition is essentially a vital operation, that it is placed under the control of the extreme ramifications of a particular system, to which we have referred all the vegetative or organic operations which characterise the animal kingdom; that it is performed in all animals, except the very lowest, through the medium of circulating organs, and in the highest as a consequence of certain preparatory processes; that it requires in man and in the higher animals a capillary circulation for its performance, but that neither of the capillary apparatuses which have been contended for is sufficient of itself to perform this function, although the most simple apparatus, whilst under the dominion of the vital in-

fluence of that particular structure which we find every where disseminated where there is life, is all that is requisite as the material instrument of the process;—and lastly, and as a consequence of the foregoing position, that nutrition is modified, controlled, increased, or even annihilated, either generally or in particular parts of the body, by the state of the vital influence allied to the material organisation, to which we have already imputed it, according as this particular organisation in its centres and ramifications throughout the animal frame is generally or locally affected.

OF THE DECUSSATION OF THE OPTIC NERVES, AND MOTIONS OF THE EYES, &c. &c.

(NOTES EE. See pp. 201—206.)

I. *Decussation of the optic nerves.*—Vicq d'Azyr found, on examining with a microscope a horizontal section of the optic nerves of the human subject, after it had been hardened in alchohol, that the medullary fibres occupying the exterior side of the optic nerve proceed in a direct manner from the optic thalamus to the eye of the same side, and that the place of union presents a homogeneous tissue. The Wenzels came nearly to the same conclusion from their observations; but remarked, in addition, that while the fibres of the exterior side of the nerve go immediately to the eye of the same side, those fibres placed in its interior side are directed obliquely towards the other nerve, without, however, any crossing of fibres being manifest at the point where the junction of both nerves takes place.

M. Treviranus has, in a great measure, confirmed these observations on the male *simia aygula.* The nerves and brain were left during some months in alcohol, and afterwards kept some time in caustic potash to soften them. Having thus prepared them, he submitted them to a careful dissection, when he made out, with the aid of a microscope, that the external fibres of the upper side of each were continued from their cerebral extremity to that in the eye, without uniting themselves to those of the other side; whilst, on the contrary, the internal and inferior fibres of one nerve went to the other side, and united with the fibres of the opposite nerve. It was difficult to determine whether any of the fibres actually passed from one side to the other. He thought, however, that some of the fibres did so. The internal fibres, thus interlacing together, were evidently more numerous than the external fibres which ran to the eye without uniting with those of the opposite nerve.* M. Magendie infers from his experiments that the decussation of the optic nerves is complete.†

II. *Of the motions of the eye, p.* 206.—Mr. Charles Bell has lately examined the motions of the eye, in illustration of the uses of the muscles of the orbit; and has shewn, in the first place, that there are motions performed by this organ not hitherto noticed. Every time the eyelids descend to cover the transparent part of the eye, the eyeball ascends, or suffers a revolving motion. If this were not the case, the surface of the eye would not be moistened, nor freed from offensive particles. He has proved, in the next place, that during sleep the eyeball is turned up, and the cornea lodges secure and moistened by the tears, under cover of the upper eyelid. He considers that these motions are rapid and insensible, and that they are provided for the safe-guard of the eye. The other motions are voluntary, and for the purpose of directing the eye to objects.

Mr. Bell next examined the actions of the muscles of the eyeball, and distinguished them, as usual, into the straight and oblique muscles. It has been supposed, hitherto, that both these classes of muscles were voluntary; some describing the oblique as coadjutors of the recti muscles, and others as opponents to the recti; but Mr. Bell has viewed the oblique as provided for the insensible motions of the eyeball, and the recti for those motions which are directed by the will, and of which we are conscious.

Mr. B. has also proceeded to shew, that the consciousness of the action of the recti muscles gives us the conception of the place or relation of objects; and has endeavoured to prove, by observation and experiment, that the actions of the straight muscles are inseparably connected with the activity of the retina, that is, with the enjoyment of vision; but that the moment the vision is unexercised, the eyeball is given up to the operation of the oblique muscles, and the pupil is consequently drawn up under the eyelid. "Hence the eyes are elevated in sleep, in faintness, and on the approach of death; and that distortion which we compassionate as the expression of agony, is the consequence merely of approaching insensibility."‡

III. *Of the connexion of the fifth pair of nerves with the function of vision.*—The branches of the fifth pair of nerves are evidently related to the functions of sensation and touch in respect of the parts to which they are ramified. In a few of the lower animals in which the optic nerve is wanting, the first branch of the trigeminal nerve seems to be so intimately connected with the sense of vision, as to be entitled to be considered as the chief nerve of this organ, and the one on which the sensation depends. It seems also, both from experiment and pathological observation, to be subservient in the higher animals to the perfection of the sense of vision; and it supplies in an especial manner some of the parts of the organ, particularly the iris, most intimately associated in function with the retina. The fifth pair of nerves seems to establish a kind of relation between the senses of sight, smell, taste, and hearing, by means of the filaments proceeding from its three principal branches to the most important parts of the organs of these senses; and whilst it contributes to their perfection generally, it is particularly concerned in the production of the sense of taste. It is not a special or principal nerve of sight, nor of smell, nor of hearing, in man, but it performs an accessary part, and renders these senses more perfect.

M. Serres§ records a case of disease confirmatory of these views, which occurred in an

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* *Journal Complémentaire*, Oct. 1823.

† See his compendium of Physiology, 2d edition.

‡ Annals of Philosophy, May 1823.

§ *Archives Générales de Médecine. Août* 1824.

epileptic patient in the hospital *la Pitié*. The patient had lost the sight of the right eye, and the senses of taste and smell of the same side; hearing also was nearly lost in the right ear. Upon dissection, the fifth pair on the right side, at its origin, was converted into a yellowish gelly-like substance, and wasted to less than two-thirds the size of the nerve on the opposite side. The ganglion was also yellowish and diseased. The muscular fibres of the affected nerve seemed healthy: mastication was not observed to have been affected.

When the first branch of the fifth pair is injured, or its functions impeded or destroyed, either by experiments, by accidents, or disease, the more important parts of the eye become inflamed or otherwise diseased, sometimes to an extent sufficient to destroy the organ.

IV. *Of the adaptation of the lens to distinct vision.*—The majority of physiologists have considered adaptation of the crystalline lens to the objects observed as a matter of fact. Haller, however, seemed to have entertained a different opinion, and to have denied that any adaptation of the lens obtains. This opinion has recently been ably supported by the reasoning of Dr. Milligan, the learned translator of M. Magendie's Compendium of Physiology. Dr. Milligan states, that "the human eye is a camera obscura, and, like it, receives the image of every object accurately at every distance." But although we have no satisfactory proof that any adjustment of the lens actually takes place, yet we conceive that some adaptation of the eye, particularly as respects the motions of the iris, and the resulting effects upon the cornea, may be observed. On this subject, the most exact and conclusive observations which have hitherto been adduced have been made by Jean Mile, professor of physiology in the University of Warsaw.* The inferences at which he has arrived are as follow:—

1. The eye does not see with the same distinctness objects at all distances, but only when placed within a certain distance. 2. This does not proceed from external causes, such as the diminution of the optic angle, and the obscuration of the object by the intermediate air; for to see clearly, and to see distinctly an object, are not identical. 3. The causes of distinct vision are internal, and situated in the eye itself; they are two in number, one disposes the eye for continuous distinct vision, the other for transient distinct vision of objects at different distances; but neither of them can act but within certain limits. 4. These limits are greater for the presbyote than for the myope. 5. These faculties both depend upon the action of the iris, which acts at the same time in two ways to produce two effects; first, the contraction of its aperture, and secondly, the flexion of the cornea; the alteration in the size of the pupil being only visible. 6. The adjustment of the eye for continuous distinct vision of objects contained within certain limits depends not upon the greater density of the vitreous humour at the bottom of the eye than towards the lens; 7, but is owing to the disfraction of the rays of light near the edge of the aperture of the iris, in consequence of which there are formed, by a single external luminous point, several foci instead of one, ranged successively in a line of a certain length, so that the object may change its distance within certain limits, and yet one of its foci shall always fall on the bottom of the eye. 8. This focal length is inversely as the magnitude of the pupil. 9. The circumference of indistinct objects appears radiated, and to the phenomenon of confusion are added the motion and multiplication of the image when the edges of bodies are brought near the side of the fasciculus of rays which enter the eye; besides, the prismatic colours also appear. 10. All these phenomena, which are observed in an eye performing its functions, may be produced by an apparatus the structure of which resembles that of the eye, and even by a common lens, substituting for the motions of the iris diaphragms or screens of different sizes. 11. The nature of all these phenomena proves, that disfraction is their common origin, and they may constitute a separate kind of optical illusions, proceeding from disfraction. 12. The second cause which disposes the eye for the momentaneous distinct vision of objects, depends neither upon the action of the external muscles of the eye, nor the advancement of the bottom of the eye, nor in change of form or position of the crystalline lens; but appears to be owing rather to the change of curvature of the cornea by the contraction of the iris, which takes place when the eye adjusts itself to see very near objects, as is proved by the simultaneous approximation of the pupil.

OF THE NERVES CHIEFLY CONCERNED IN THE SENSE OF SMELL.

(Note FF. See p. 314.)

The first pair of nerves is chiefly distributed to those parts of the nasal apparatus which are principally concerned in this function; namely, the olfactory or pituitary membrane, particularly at the upper parts of the nasal cavities, and where it covers the spongy and convoluted bones. The nasal branches of the fifth pair are distributed rather to the accessary parts of the organ, than to the pituitary membrane itself; they form a circle around the expansions of the olfactory nerves, in the same manner as the ciliary nerves around the retina. The first pair of nerves generally presents a size and developement in proportion to the energy of smell, in the more perfect animals; whilst, on the other hand, it must be conceded, that the fifth pair is the chief nerve of smell in fishes and the *cetaceæ*. It was formerly doubted by Mery,† that the first pair of nerves are actually the nerves of smell; and recently M. Magendie‡ has revived these doubts, and appealed to experiments in justification of them. That the first pair are most intimately connected with the function of smell, seems proved by the following facts: Loder§ found the olfactory nerves destroyed in a man who was entirely deprived of the sense of smell. A similar fact came un-

* De la Cause qui dispose l'Œil pour voir distinctement les objects placés à différentes distances.—*Traduit du Polonais. Journal de Physiologie*, tom vi. pp. 166, 179, *et seq.*

† Brunet, *Progrès de la Médecine*, 1697.

‡ *Journ. de Physiol. Exper.* tom. iv. p. 169.

§ *Observatio Tumoris Scirrhosi in basi Cranii reperti.* Jenæ, 1779.

der the observation of Oppert;* and Cerutti† relates the case of a man who had never enjoyed the sense, and in whom, upon dissection, the olfactory nerves were ascertained to have been entirely wanting.

It should not, however, be concealed, that Mery adduced equally conclusive facts, in proof of the second branch of the fifth pair being the chief nerve of this sense. He opened the heads of three persons who had experienced no defect of the sense of smell, and in whom the first pair of nerves was changed, so as apparently to have been incapable of performing their functions.

In our speculations respecting the sense of smell, it should be recollected that, in order that this function may be duly performed, the pituitary membrane must be constantly moistened by a fluid mucous secretion. This secretion requires a continued supply of nervous influence to promote it, under the constant evaporation it is experiencing by the currents of air passing over it; and such influence we conceive to proceed chiefly from the first pair of nerves; these nerves performing, perhaps, in addition, the office of transmitting the impression made upon the pituitary membrane to the brain, or being assisted in this part of their functions by the second branch of the fifth pair; and, perhaps, this latter nerve may become the chief medium of the sensation in those cases where the first pair of nerves has been injured or destroyed.

It should be recollected, that impressions made upon the organ of smell, owing to the odoriferous particles having in some measure combined with the mucus covering the pituitary membrane, will continue for some short time after they have been made, and that they powerfully affect the state of the brain and of the nervous system, and even also influence the amorous propensities, and the states of the genital organs.

OF THE FORMATION OF THE SPINAL MARROW AND BRAIN.

(Note GG. See pp. 229, 235—238.)

I. *Of the formation of the spinal marrow.*—The researches of MM. Gall, Tiedemann, the Wenzels, Doellinger, Carus, and Desmoulins, have furnished us with much interesting information on this subject, and which, as far as we are enabled to judge from some observations made by ourselves, seems to be, upon the whole, extremely correct.

The soft and gelatinous state of the embryo at the earliest periods of its existence, the rapidity of its metamorphosis, and the difficulty of demonstrating, owing to its colour and consistency, that part of the nervous system which, from the circumstance of its supplying those parts of the embryo that are first formed, as well as from other considerations, we are led to consider as the first which assumes an organised appearance, combine to render the exact origin of the spinal marrow difficult, if not impossible of demonstration. Reasoning from the condition of the nervous system throughout the scale of the animal kingdom, from the manner in which the different organs seem to be formed, from the organisation of some monstrous fœtuses, and from other considerations on which we cannot enter at this place, we are disposed to conclude, in opposition to the opinions of some of the writers alluded to, that the spinal marrow is itself produced from the ramifications of the sympathetic ganglia; that the semilunar ganglion is the first part of the nervous system to assume an organised state; and that the subordinate ganglia, the spinal marrow, and lastly the brain, come successively into existence, and gradually arrive at their full developement.‡

It is not until about the *third* or *fourth week* that a grayish-white fluid may be detected in the cavities of the head and spine. From the *fourth* to the *fifth week* the *medulla oblongata* may be distinctly seen. It is then about twice as thick as the *medulla spinalis*, which, before the developement of the limbs, is of an equal thickness throughout its whole length, and presents a slight curvature near the commencement of the *medulla oblongata*, owing to the flexion of the head upon the chest. The spinal marrow at this time consists of two white strips of medullary matter, which offers a manifest decussation at the place where it curves forwards at the margin of the inferior extremity of the pyramids. It is not, however, the whole of the two cords of the marrow that cross, but the middle or pyramidal fasciculi of each. The spinal marrow descends from this point through the whole extent of the canal to the interior of the caudal prolongation.

At the *fifth week* these stripes or cords form, by the junction of their interior and anterior margins, a longitudinal gutter: their external and posterior margins are then full and prominent.

At the *seventh week* the spinal marrow is open throughout its whole length. On each side of the fourth ventricle a straight thin lamina is put forth, which inclines from without inwards,

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* *Dissertatio de Vitiis Nervorum organicis.* Berlin, 1815.

† *Beschreibung der Pathologischen, &c.* p. 208. Leipsig, 1819.

‡ The inferences contained in the above paragraph was first published by us in 1820, and subsequently, in the former edition of the Appendix to this work, which appeared at the commencement of 1824. We are induced to state this, because we conceive ourselves entitled to whatever credit may belong to the having been the first to state the above facts. Late writers, in their allusions to this subject, have referred to the writings of Gall, Serres, and others, who have stated somewhat similar facts and views, but at a period posterior to that at which our observations were made and published. The first volume of M. Serres' work, which contains and illustrates some views similar to those which we had advanced, was not published till late in 1824. And M. Gall's work on the functions of the brain, which contains similar facts to those previously insisted upon by us, respecting the gradual developement of the nervous system, we did not see until the distinguished author did us the honour of presenting us with a copy of it in 1826; and it was published between the years 1822 and 1826. Our examinations into this subject, and into the gradual developement of the nervous system through the different classes of animals, commenced as early as 1813, whilst enjoying uncommon facilities for such investigations, in the northern islands of Scotland.

applying itself to that of the opposite side, without, however, uniting with it: these are the rudiments of the cerebellum, springing from the restiform bodies. The cervical enlargement begins to appear, particularly its cephalic extremity. The formation of the limbs coincides with that of the corresponding enlargements of the cord. The longitudinal raphe, formed by the approach of the interior margins of the two cords constituting the marrow, is continued upwards, and separates the tubercles, that is, the laminæ which represent them: the optic thalami are developed.

At the commencement of the *third month* the marrow is still open at its superior half, and extends from the extremity to the sacrum. The *tubercula quadrigemina* are voluminous, hollow, and separated by the median furrow: the optic thalami are full. The two cervical and lumbar prominences are a third of a line thicker than the body of the marrow: M. Tiedemann has not observed the junctions of its exterior margins until the end of the third month. M. Serres has seen it a fortnight earlier. This junction takes place from beneath upwards.

At *twelve weeks* the marrow extends only to the middle of the sacrum. The *tubercula quadrigemina* are united and form a canal: at this period the mammillary eminences and the *corpora striata* may be seen. The internal canal, which is now formed by the junction of the margins of the marrow, communicates with the fourth ventricle. According to M. Desmoulins, this canal results from a sinus, formed by the fold of the pia mater, as it dips into the interior of the marrow, or rather between both the cords of which the marrow is then formed. The precise period at which this canal is completely obliterated, has not been ascertained. M. Carus conecives that the pectoral portion of the marrow is the first to close, and that the canal is obliterated along its whole extent owing to the formation of the gray substance.

At the *fourth month* the spinal marrow reaches only to the base of the sacrum; the cervical eminence is larger than the lumbar. The two contiguous cords of the marrow divide, in the medulla oblongata, each into three others much smaller. The internal or pyramidal forms a tolerably broad surface, as in fishes and reptiles, and evidently crosses, as was already noticed, with that of the other side, about the fourth or fifth week of the fœtal life. The middle cord, or the *corpus oblivare*, is placed above the former; some of its fibres ascend to the *tubercula quadrigemina*, and unite with those proceeding from the opposite side, in order to form the vault of the aqueduct of *Sylvius*. The external or restiform cord, proceeding from the lateral and posterior portion of the marrow, forms the prominent paries of the fourth ventricle, and advances into the cerebellum. At this period the annular protuberance is perceptible. The interior canal of the marrow is now very narrow, and still communicates with the fourth ventricle. It is not until towards the end of the fourth month that the lumbar and sacral nerves become elongated, and form what has been improperly called the *cauda equina*, which at first does not exist. The pia mater, which penetrates by the posterior median furrow, is observable in the centre of the marrow.

At the *fifth month* the pyramidal eminences are evident: there still exists a communication between the fourth ventricle and the canal of the marrow. The two swellings of the cord are well marked. The annular protuberance becomes more distinct, and the *corpora striata* are large. The increased thickness of the tubercles has narrowed considerably the cavity which they formed by their approach. The marrow extends at this period no farther than the margin of the fifth lumbar vertebra.

The human embryo possesses a caudal prolongation until the fourth month of uterine life. At this period it disappears, and its disappearance coincides with the ascension of the spinal marrow in the vertebra canal. If the ascension of the marrow is arrested, the human fœtus is born with a tail, as has been observed in several cases. The circumstance of the spinal marrow descending lower in the vertebral canal the younger the fœtus, has attracted the particular notice of those physiologists to whose researches we are indebted for our knowledge of the subject under consideration. M. Tiedemann, who offers the most rational explanation of this phenomenon, supposes that the marrow descends not so far in the canal of the full-grown fœtus as in that of the early embryo, because the vertebral column grows more rapidly in length than the nervous chord which it is destined to protect.

Towards the end of the *sixth month* the *corpora olivaria* form a well-marked lateral projection. At this epoch may be seen the internal and middle chords, forming the peduncles of the brain, plunging into the optic thalami, which they formed by their enlargement. The fibres composing them may be perceived on scraping away a thick pulpy layer from their interior and superior aspect. A few fibrous portions detach themselves from their internal side, and proceed outwards to the mammillary eminence. All the other fibres continue to advance from behind forwards, and from within outwards, beneath the corpora striata, and proceed, in a diverging form, to the cerebral lobes. A few fibres may be seen entering them. In the course of the sixth month the transverse furrow separating the *eminentia quadrigemina* begins to appear, or rather, each of these prominences becomes more developed.

At the *seventh month* the length of the marrow is nearly the same. The transverse fibres which compose the annular protuberance are now distinct, and they may be seen interlacing with those of the pyramids. This part results from the following disposition: the fibres of one lateral hemisphere of the cerebellum are continued beneath the spinal marrow with the fibres of the opposite hemisphere, by layers which alternate with the planes of fibres proceeding obliquely from the pyramids to the optic thalami.

At the *eighth month* the marrow reaches only to the fourth lumbar vertebra, and at the *ninth month* it is at the margin of the third. The interior canal of the marrow still exists, and remains until from six months to a year after birth. It is at the last months of gestation that the disposition of the medullary fibres of the marrow may be most distinctly traced, and the mode of formation of the mesocephalon or *pons Varolii*, which is only a continuation of the marrow, becomes most evident.

All the white or medullary parts which are seen at the base of the brain, manifestly arise from the superior part of the spinal marrow.*

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* Ollivier *sur le Développement de la Moëlle Epinière.*

II. *Of the formation of the brain.*—The interesting results of Dr. Tiedemann's researches on this subject may be reduced to the following heads:

"1. In the commencement of pregnancy, especially about the second month, the earliest period at which the brain can be rendered perceptible by the action of alcohol, this organ is very small in proportion to the spinal marrow. In fact, it results from the prolongation upward and forward of the two principal chords, the olivary and pyramidal. All its superior part is open, or, more properly speaking, forms a broad gutter, which at once comprehends the third ventricle, the aqueductus Sylvii, the fourth ventricle, and calamus scriptorius. This gutter is uninterruptedly continuous with the canal which traverses the whole length of the marrow.

"2. The cerebellum evidently originates from the spinal marrow; from the lateral parts of which arises on each side a small flattened chord. These two, at first so distinct and separate that they may be readily parted without laceration, afterwards unite so as to form the roof of the fourth ventricle. Then only the brain, viewed from above, ceases to represent a gutter; and the laminæ and branches of the cerebellum are formed at a much later period.

"3. The mass which supports the tubercula quadrigemina equally shews itself in its origin, under the form of two small thin membranes, which arise from the olivary chords of the spinal marrow, and which, when they cease to be distinct, represent a vault covering a large ventricle, whose successive contraction gives rise to the aqueductus Sylvii.

"4. The pyramidal chords of the spinal marrow, which take a direction below upward, and from behind forward, after having produced two swellings or ganglia, the optic thalami and corpora striata, each terminate by a lamina, which, bent from before backward, and from the side towards the superior and internal part, forms the commencement of the hemisphere of the brain. These membranes and thin hemispheres are so small at the second month that they scarcely cover the corpora striata. In proportion as they increase they extend backward, and cover, at the third month, the optic thalami; at the fourth, the tubercula quadrigemina; and at the sixth or seventh, the cerebellum. The lateral ventricles result from their inversion.

"5. The medullary fibres of the pyramidal chords, previously to the formation of the tuber annulare, are immediately continuous with those of the crura cerebri; from whence the eye may readily trace them in the optic thalami and corpora striata, and see them afterwards spreading and radiating in the hemispheres.

"6. The parietes of the hemispheres gradually increase in thickness in proportion as new strata of cerebral substance are deposited on their surface; and convolutions are not decidedly seen till towards the close of pregnancy.

"All these combined facts clearly demonstrate, in the opinion of Dr. Tiedemann, that the brain and cerebellum proceed from the spinal marrow; or that, to employ a modern expression, they are an efflorescence of it. In running through the scale of animals, ample confirmation may be found of the assertions here advanced. The structure of the encephalon and spinal marrow becomes complicated in proportion as we ascend from fishes to reptiles, birds, and mammalia. If the contrary opinion were correct—if the spinal marrow were derived from the brain—the cerebrum and cerebellum must necessarily be found the first formed in the fœtus, which is not the case. It is equally necessary that, in the animal scale, where it is impossible to mistake a gradation in the figure and developement of the organs, that a complete brain should exist previously to any trace of a spinal marrow; but this is never observed. Comparative anatomy, on the contrary, shews that the spinal marrow is very large in the inferior classes of animals, while the brain forms but a small and delicate prolongation of it; and in ascending from reptiles to birds and mammalia, it is seen gradually to increase in volume and complication, as absolutely takes place in the fœtal encephalon."*

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* Prochaska and Wenzels conclude, from their microscopic observations, that the brain is composed of a number of small globules, of a tolerably firm consistence, contained in a flocculent pulp. The researches of M. Bauer into the ultimate structure of this organ are more precise. He considers that the brain and nerves consist of extremely delicate fibres, formed of minute globules, connected together by a transparent gelatinous fluid, or viscid mucus, which is soluble in water. These globules vary in dimensions, from $\frac{1}{2800}$ to $\frac{1}{4000}$ parts of an inch. "The principal difference," he states, "in the appearance of the different parts of the brain, consists in the proportions which the quantity of mucus and fluid bear to the quantity of globular tissue, and, in some measure, in the size of the globules. The cortical substance of the cerebrum and cerebellum is made up by the small globules, the gelatinous fluid and mucus being very abundant. The medullary substance in the cerebrum and cerebellum differs from the above, in the large globules prevailing, the mucus being more tenacious and less abundant. The crura cerebri and cerebelli resemble the medullary substance, only that the mucus and fluids are more abundant, and in greater proportion than the globules. The medulla oblongata, the corpora pyramidalia and olivaria, have nearly the same structure as the medullary substance, but the mucus is very abundant. In the medulla spinalis the mucus and fluid are less tenacious, but in greater quantity than in any part of the brain.

Every part of the brain is pervaded by innumerable blood-vessels, which are of considerable size towards the centre, and branch out to an extreme degree of minuteness; but even then carry red blood. The arteries in the brain never anastomose, and are accompanied by veins still smaller, which are supplied with valves.

This view of the structure of the cerebrum and cerebellum is calculated, in the opinion of Sir Everard Home, to throw considerable light on the functions of the brain. He thinks that the cortical substance is one of the most essential parts of this organ, and considers it the seat of memory, from having observed that that faculty is destroyed or materially diminished by any undue pressure upon the upper anterior part of the brain, as in that requiring the operation of trepan. In hydrocephalus, on the other hand, where the fluid is in large quantity, and there only remain the cortical part of the brain and pons Varolii, all the functions go on, and the memory can retain passages of poetry. In one

III. *Cerebri generatim, cerebelli et cerebri speciatim, pondus, à statu embryonis usque ad decrepitam hominis ætatem.*—(Wenzels' "De penitiore Cerebri Structurâ."*)

ÆTAS.	Pondus totius cerebri.	Pondus cerebri.	Poudns cerebelli.	Ratio cerebri in cerebellum.
	Grana.	Grana.	Grana.	
Embryo Masculus quinque ferè mensium	720	683	37	$18\frac{17}{37}$: I
Embryo Fœmineus septem mensium . .	2310	2160	150	$14\frac{2}{5}$: 1
Embryo Fœmineus octo mensium . . .	4960	4610	350	$14\frac{6}{35}$: 1
Puella recens nata	6150	5700	450	$12\frac{2}{3}$: 1
Puella triennis	15240	13380	1860	$7\frac{6}{31}$: 1
Puer triennis	13050	11490	1860	$7\frac{57}{130}$: 1
Puella quinquennis	20250	17760	2490	$7\frac{11}{83}$: 1
Vir quindecim annorum	24420	21720	2700	$8\frac{6}{135}$: 1
Vir octodecim annorum	20940	18474	2466	$7\frac{2}{4}$: 1
Vir viginti duorum annorum	21820	19040	2760	$6\frac{62}{69}$: 1
Vir viginti quinque annorum	22200	19500	2700	$7\frac{6}{27}$: 1
Vir triginta unius anni	24120	21480	2640	$8\frac{3}{21}$: 1
Vir quadraginta sex annorum	20490	18060	2430	$7\frac{35}{81}$: 1
Vir quinquaginta quatuor annorum . .	20580	18270	2310	$7\frac{21}{23}$: 1
Vir quinquaginta sex annorum	22590	20070	2520	$7\frac{81}{84}$: 1
Vir sexaginta trium annorum	22500	19780	2720	$7\frac{37}{126}$: 1
Vir septuaginta duorum annorum . . .	22620	20200	2420	$8\frac{42}{121}$: 1
Vir octogenarius	19080	16500	2580	$6\frac{61}{129}$: 1
Vir octoginta octo annorum	23970	21210	2760	$7\frac{63}{92}$: 1

IV. *Of the cephalo-spinal fluid.*—The recent researches of M. Magendie† have shewn that there exists around the cerebro-spinal axis a copious exhalation of a limpid fluid, contained between the pia mater and the arachnoid. This fluid seems to be an additional protection to the nervous masses against sudden shocks and concussions. M. Desmoulins says, that it is met with more abundantly in mammiferous animals than in fishes and birds. M. Magendie states, that it gradually disappears after death, so that but little remains twenty-four hours after this event. In experiments upon living animals it has been found in so great a quantity as to be thrown out to the distance of several inches when the canal has been punctured as deep as the pia mater. It is most abundant in the cervical and lumbar regions, and at the height of the fourth ventricle: it flows not only from the spinal canal to the cranial cavity, but also from the exterior of the cerebrum into its ventricles. According to M. Magendie, the fourth ventricle communicates with the external surface of the cerebro-spinal masses, and consequently with the external space in which this fluid is contained, by means of a round opening, which he calls the aqueduct, situated between the two posterior arteries of the cerebellum. This opening he calls the *entrance into the cerebral ventricles;* and through it this fluid passes and repasses into the fourth ventricle, and through this latter into the third and lateral ventricles; a flux and reflux of the fluid taking place from the brain to the spinal canal, and *vice versâ*, during the motions of the brain occasioned by respiration, and according to the varying circumstances of the parts contained in the cranial and spinal cavities.

This fluid seems to adapt itself to the positions, movements, and conditions of the brain and spinal chord; to be diminished when the blood-vessels of the brain are congested or injected; to preserve a certain degree of pressure, by becoming more abundant when the brain is either less vascular or of diminished bulk; and to protect the cerebro-spinal nervous masses

case, slight pressure upon the sinciput produced complete derangement, and violent excesses of the passion of lust, which went off by removing, by the trepan, the depressed bone.

The veins being so minute, and being supplied by valves, perform, in the opinion of this physiologist, the office of absorbents, which have never been observed in the brain, and carry the absorbed matter into the superior longitudinal sinus, which appears more a reservoir than a vein.

The transparent mucus being not only one of the most abundant materials of which the brain itself is composed, but also the medium by which the globules are kept together, and serving the same purpose in the nerves, Sir E. H. thinks that the communication of sensation and volition depends upon it. He concludes, from all his experiments and observations, that this fluid, as well as the principal materials of which the body is composed, are met with in the blood.

* It will be perceived that the Wenzels have given these as the whole of their observations, and not as the mean of numerous experiments made to ascertain the medium results at each particular epoch of life.

† *Journ. de Physiol. Experiment.* t. vii. p. 1; t. viii. p. 211.

from the effects of concussions and external injuries. In its constitution it resembles in every respect the most limpid of the serous exhalations of the body. M. Magendie says, that he has found it very abundant in idiots and persons of weak intellects, and, on the contrary, in small quantity in those whose intellectual faculties were active and fully developed: hence he is led to infer that the quantity of this fluid is in an inverse ratio to the developement of the mental faculties.

OF THE FUNCTIONS OF THE CEREBRO-SPINAL SYSTEM OF NERVES.

(NOTES G G. See pp. 235—238, *et seq.*)

I. *General view of the nervous system through the different classes of animals.**—At a former part of these notes we divided the nervous system into two principal orders, viz. the *ganglial* or vital, and the *cerebro-spinal*. Of the former we remarked, that the globules of which it is constituted are disseminated in the structure of the *Zoophyta;* are organised into a homogeneous ganglion, but imperfectly developed, in many of the orders of the *Echinodermata;* and are arranged into ganglia, communicating by means of intermediate chords, in the *Annelides, Cirrhipedes*, &c. The homogeneous nature of the ganglions disappears as the animal is provided with separate organs, especially with those devoted to the senses; and, with the developement of separate organs, accessary or subordinate ganglions make their appearance, which latter, in the progressive rise in the scale of the animal kingdom, assume, in the anterior part of the body of the animal, the character of the rudiments of an encephalon. So long as there exists only simple ganglia without any spinal chord, the ganglion representing the rudiments of an encephalon surrounds the œsophagus in the manner of a ring. This encephalic ganglion is intimately connected with the ganglial functions, and presides over those imperfect operations of sense with which the animal is endowed, and which are those more immediately subordinate to its functions of nutrition, and to its immediate preservation.

In all animals possessing no other rudiments of a cerebro-spinal system than an accessary ganglion disposed around the œsophagus, the manifestation of volition is by no means distinct; their movements appear to be the result neither of reflection nor of choice. An obscure instinct seems to be the actuating principle of those operations, which may assume in them the nearest resemblance to those of volition.

As we rise in the scale of the animal creation, and as we perceive the relation between the exterior world and the animal to be more extended and intimate, owing to the extension and perfection of the organs of sense and volition, so we perceive the cerebro-spinal system more perfectly organised, more fully developed, and more complicated in its structure. With the formation of the spinal chord, in the class of fishes,† the accessary encephalic ring or ganglion disappears, and the encephalon is surrounded by a protecting case, which is continued over the chord itself.

The diversity and complication of the parts constituting the encephalon increase as we rise through the four superior classes of animals. In the *Hymenopteræ*, especially in the bees, each sensorial nerve possesses an enlargement in the encephalon appropriated to itself, from which it takes its origin; but all these enlargements coalesce in a central mass composed of two symmetrical hemispheres, the prototype of the cerebral hemispheres of all the superior classes.

In another part of these notes we gave a full detail of the progressive developement of the cerebro-spinal system of nerves in the human fœtus. It will readily appear, from what we there advanced, that a similar gradation (from the simplest to the most complicated and perfect state of the nervous structure) to that which we observe in ascending the scale of the animal creation, may be remarked in the changes which the nervous system undergoes in the progressive evolution of the human embryo. In the lowest of all the animal kingdom the nervous matter is not organised in a manner distinct from the tissue constituting the animal; the nervous globules are disseminated through an amorphous and pulpy mass. As we ascend the scale we perceive this particular structure arranged in succession into ganglia; then into ganglia and a spinal marrow; and, lastly, into ganglia, a spinal marrow, and a brain; each becoming more perfect as we ascend the scale, and the gradation from the one to the other being nearly unappreciable in the species or genera, but sufficiently remarkable in the orders. A developement of the nervous system, in which a similar progression to this is observed, takes place in the formation of the human fœtus and in that of the most perfect animals; and a similar type to that in which this system exists in the lower orders, is adopted at first in the highest, and preserved,—every successive state of organisation which this system assumes in its progressive developement being additions to that previously adopted, whilst, in the process of formation as respects the entire animal, each intermediate series from the lowest, which is its first state of existence in the embryo, is successively passed through, until the fœtus arrives at that specific condition and stage of organisation bestowed on the species to which it belongs. Thus the human fœtus, in the progress of its formation, as respects both its nervous system and other organs and textures, runs through the different grades of organisation,

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* This section is reprinted *verbatim* as it stood in the former edition of these Notes, and contains the same statements which were made public by us as early as 1820. But, even as late as the date of the former edition of this work, we are not aware that similar sentiments had been published elsewhere.

† M. Desmoulins has lately shewn that many reptiles and several fishes offer not a trace of gray substance in their spinal chords, and that, on the contrary, this part is entirely composed of white substances. He has also found that the sturgeon is entirely without a cerebellum; and that its fourth ventricle possesses a considerable extent. He concludes that the dimensions and extreme developement of the fourth ventricle always coincide with the extreme developement of the eighth pair of nerves. The circumstance of the gray substance being wanting in the spinal chord of some fishes, militates against the opinion of M. Ollivier stated at a subsequent page.

from the lowest to that at the head of which it is itself placed.*

II. *Of the functions of distinct parts of the cerebro-spinal order of the nervous system.*—The researches of M. Flourens into the functions of the cerebro-spinal order of nerves, have lately added greatly to our knowledge as to actions in which distinct portions of this part of the nervous system are more particularly concerned. But before we can give any account of the conclusions at which he has arrived, we must briefly notice the meaning he has attached to some of the terms which he employs.

The term *contractility* he very properly limits to the property inherent in the muscular fibre only, of undergoing brisk contractions under the application of stimuli; and the term *sensibility*, to imply the property of experiencing sensations. The word *irritability* he applies to the property of exciting sensation and motion, without evincing or experiencing them. This application of the word is by no means judicious; it must, however, be allowed, that it is not easy to find a term which can convey the meaning wished to be attached to it.

The questions proposed by M. Flourens, and which he has endeavoured to ascertain by experiment, are:—1st, from what points of the nervous system artificial irritation may set off to arrive at a muscle; 2d, to what points of this system an impression must be propagated to produce sensation; 3d, from what points voluntary irritation descends, and what parts of this system must be influenced to produce it regularly.

M. Flourens commenced with the *nerves*, and fully confirmed the views usually entertained respecting their functions. He has shewn, in a satisfactory manner, "that, in order to effect contraction, a free and continued communication is requisite between the nerve and muscle; and that to produce sensation, a similar communication with the brain is equally necessary. Hence, he concludes, that neither contraction nor sensation belong to the nerve; that these two effects are distinct; that they may take place independently of each other; and that these propositions hold good, at whatever part, and in whatever branch of a nerve, the communication is interrupted.

"Employing the same method with regard to the *spinal marrow*, he arrived at similar conclusions. When it is irritated in any given point, contractions are excited in all the muscles which derive their nerves from below this point, if the communication remains free; but not if the communication be intercepted. Exactly the reverse obtains with regard to sensation; and, as in the nerves, the government of the will requires the same freedom of communication as sensation, the muscles beneath the intercepted part no longer obey the animal, and he has no feeling in them: in fine, if the spinal marrow be intercepted at two points, the muscles which receive their nerves from this interval experience contractions alone; but the animal *does not command them*, nor receive from them any sensation." M. F. farther inferred, from his experiments respecting the functions of the spinal marrow, that sensation and contraction belong no more to it than to the nerves.

He next directed his researches to the *brain*, in order to ascertain the point whence irritation departed, and the point where sensation arrives, and to determine their respective co-operation in acts of volition. Advancing from the *medulla oblongata* towards the hemispheres, M. Flourens first examined how far it was possible to go and still produce sufficient irritation on the muscular system, when he arrived at a point where these irritations disappeared: "then, taking the brain at the opposite part, he irritated it at points deeper and deeper, as long as he did not act upon the muscles; and when he did begin to act upon them, he found himself at the same point where the action had ceased in ascending. This part is also that where the sensation of irritation applied to the nervous system likewise ceases: above this, punctures and wounds do not excite pain. Thus M. Flourens pricked the hemispheres without producing contraction of the muscles, or the appearance of pain in the animal; *he removed them in successive slices:* he did the same with regard to the cerebellum; he removed at once the hemispheres and cerebellum. The animal remained passive. The *corpora striata* and the *optic thalami* were attacked, and removed without any other effect: the iris was not contracted, nor even paralysed. But, when he pricked the *tubercula quadrigemina*, trembling and convulsions began, and these increased in proportion as he penetrated into the *medulla oblongata*. Pricking the tubercles, as

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* See the further conclusions connected with this subject at which we have arrived, in the Note on the Developement of the Fœtus.

Sir Everard Home, MM. Geoffroy Saint Hilaire and Blainville, and Dr. Schultze, consider that the skeleton of animals was intended more to prevent the nervous and vascular systems from being compressed or suffering any other injury, than to give form and power of motion to the body. The last-named physiologist (*Allgemeine Encyclopädie fur Practische Arzte und Wundarzte, 1 theil, 1 band, Leip.* 1820.) concludes:—

1. "That the spinal marrow and vertebral column at all times exist together, even when only the slightest vestiges of the osseous system can yet be found.

2. "That the osseous and nervous systems have between them numerous intimate relations, both physiological and pathological.

3. "That the more the exterior hard envelopement penetrates the interior of the body, and approaches towards the nervous system, the more also are the phenomena of sensibility developed, and *vice versâ*.

4. "That the organs possess more or less importance according as they are more or less protected from external influence by bones."

The blood proceeding from the mass of muscles, spine, and spinal marrow, is emptied into the great spinal veins, as into a reservoir; from whence it passes into the veins placed on the sides and anterior surface of the spine, and thence into the superior and inferior cavæ.

By what power, it has been asked, is the blood which arrives in the two great spinal veins, driven from them? These veins may effect the propulsion of the blood which they contain by the vital properties with which they are endowed; or the blood may be drawn out of them, owing to their proximity to the cava, by the dilatation of the cavities of the heart; or by both influences combined.

well as the optic nerve, produced quick and continued contraction of the iris. These experiments agree with those of Lorry, published in the third volume of the *Mémoires des Savans étrangers*. 'Neither the irritation of the brain, nor of the *corpus callosum* itself, produces convulsions: it may even be removed with impunity. The only part among those contained in the brain which has appeared uniformly and universally capable of exciting convulsions, is the *medulla oblongata*: it is this part which produces them, to the exclusion of every other.' They contradict the experiments of Haller and Zinn, with regard to the cerebellum; but, from what M. Flourens has seen and pointed out, it appears that these physiologists had touched the medulla without being aware of it. He concludes that the medulla oblongata and tubercles are (in his language) irritable; which means that they are conductors of irritation, like the spinal marrow and nerves, but that neither the cerebrum nor cerebellum possesses this property. The author hence concludes, likewise, that these tubercles form the continuation and superior termination of the spinal chord and medulla oblongata; and this opinion is in conformity with their situation and anatomical connexions."

Wounds of the brain and cerebellum do not excite pain any more than convulsions. Hence M. Flourens infers, that to them the impression received by sensible organs must be conveyed, in order that the animal may experience a sensation. He appears to have established this proposition in a satisfactory manner with regard to the senses of sight and hearing; for when both lobes of the cerebrum are removed, the animal becomes both blind and deaf. "Instead of saying, with M. Flourens, that the cerebral lobes are the only organs of sensation, we should restrict ourselves to ascertain facts, and content ourselves with saying that these lobes are the sole receptacle where the senses of sight and hearing can be perfected, and become perceptible to the animal. If we wished to add to this, we should say that they are likewise those where all the sensations take a distinct form, and leave durable traces on the memory,—that they serve, in a word, as the seat of memory; a property by means of which they furnish the animal with materials for judgment. This conclusion, thus reduced to proper terms, becomes the more probable, in that, besides the verisimilitude which it receives from the structure of these lobes, and their connexion with the rest of the system, comparative anatomy offers another confirmation in the constant relation of the volume of these lobes with the degree of intelligence of the animal."

M. Flourens next examined the effects which follow the extirpation of the *tubercula quadrigemina*. "The removal of one of them, after a convulsive movement, which soon ceases, produces, as a permanent result, blindness of the opposite eye, and involuntary staggering; that of both tubercles renders the blindness complete, and the staggering more violent and long continued. The animal, however, retains all its faculties, and the iris continues contractile. The deep extirpation of the tubercle, or the section of the optic nerve only, paralyses the iris: from which the author infers, that the removal of the tubercle only acts as the division of the nerve would do; that this tubercle is only a conductor with regard to vision; and that the cerebral lobe alone is the seat of the sensation, the point where it is consummated and passes into perception."

M. F. next investigated the functions of the *cerebellum*, and found that, during the removal of the first layers, "there appeared only a slight weakness and want of harmony among the movements. At the middle layers a disturbance nearly general was manifested. The animal, in continuing to see and hear, only executed quick and irregular movements: the faculty of flying, walking, and keeping itself standing, were lost by degrees. When the brain was cut off, this faculty of performing regulated motion had entirely disappeared. Placed upon the back he did not rise, but continued to see the blow which menaced him; he heard sounds, and endeavoured to shun the danger which was threatened: in a word, feeling and volition were retained, but the power over the muscles was lost; scarcely could he support himself with the assistance of the wings and tail. In depriving the animal of the brain, it was thrown into a state resembling sleep: in removing the cerebellum, it was brought to a state resembling intoxication."

The reporters to the Institute on the inquiries of M. Flourens, have drawn the following conclusions "from a rigorous examination of the facts which he has established:—The integrity of the cerebral lobes is necessary to the exercise of sight and hearing: when they are removed, the will no longer manifests itself by voluntary acts. However, when the animal is immediately excited, he performs regular movements, as if endeavouring to avoid pain or inconvenience; but these movements do not effect his purpose, most probably because the memory, which has been removed along with the lobes that constituted its seat, no longer affords grounds or elements of judgment: these movements have no consistency, for the same reason that the impulse which caused them neither leaves any remembrance nor permanent volition. The integrity of the cerebellum is necessary to the regularity of locomotion: let the brain remain, the animal will see, hear, and have evident and powerful volition; but if the cerebellum be removed, he will never find the balance necessary to locomotion. As to the rest, irritability remains in parts without the brain or cerebellum being necessary. Every irritation of a nerve brings it into play, in muscles to which it is distributed: every irritation of the spinal marrow excites it in all the members beneath the point of its application. It is quite at the top of the medulla oblongata, at the point where the tubercula quadrigemina join it, that this faculty of receiving and propagating irritation on the one hand, and pain on the other, ceases. It is this point at which sensation must arrive in order to be perceived: it is from hence that the mandates of the will must emanate. Thus, the continuity of the nervous organ from this point to the different parts of the body is requisite for voluntary motion, and for the perception of impressions, whether external or internal."

Thus, then, the property of nervous irritability, or of receiving and conducting sensation and irritation, is limited to the nerves, spinal chord, medulla oblongata, and corpora quadrigemina; "the integrity of the optic thalami is not essential to the contractility of the iris; the sensations of light and of sound reside in the

cerebral lobes, and there also all other sensations acquire distinctness and durability; the spinal chord combines the muscular contractions so as to produce motion in the joints; and the cerebellum regulates these movements, and unites them so as to constitute the actions of standing and locomotion. Such are the discoveries of M. Flourens."*

III. *Of the distinct functions of the anterior and posterior columns of the spinal marrow.* — It is certain that the spinal marrow sends off nerves engaged in the performance of two distinct functions, viz. that of feeling and that of motion. From what part, we are led to ask, of this organ do the nerves allotted to each of these functions proceed? It is well known that the spinal marrow is formed of two substances — a white substance which is exterior, and a gray substance occupying the interior of the chord. The continuity of the fibres composing the roots of the spinal nerves, with the gray substance of the chord, as established by Keuffel and Ollivier, naturally leads us to suppose that it is particularly concerned in the production of the functions of sensation and voluntary motion. It may be also observed, that the fibres of the anterior roots are much smaller than those of the posterior, — a circumstance which, when viewed in connexion with what has been advanced on the subject by Mr. Charles Bell† and M. Magendie, shews that each set of fibres (posterior and anterior) is more immedi-

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* Experiments similar to those of M. Flourens were instituted in 1805, by Professor Rolando, of Turin, from which he deduced inferences in some respects the same as those at which M. Flourens has arrived. The experiments of the latter physiologist were, however, more varied, were apparently more carefully performed, and therefore were more conclusive, than those of his predecessor. They were repeated, moreover, before a commission of the Institute of France, composed of some of the most eminent of that body, who approved of the conclusions which are given above. The following are the inferences which M. Flourens considers that his experiments justify:—

"1. No movement proceeds *immediately* from the will. The will is the exciting and determining cause of certain movements; but it is never the efficient or effective cause of any.

"2. It has been shewn that the immediate cause of muscular contraction particularly resides in the spinal marrow and nerves, and that the regulating cause of these contractions is placed in the cerebellum.

"3. There are, therefore, three phenomena essentially distinct in a movement proceeding from volition: 1, the *volition* of movement, a volition which seems to reside in the cerebral hemispheres; 2, the appropriate *regulation* of the different muscular contractions productive of motion, which resides in the cerebellum; and 3, the *excitation* of these contractions, which has its efficient seat in the spinal marrow and its nerves.

"4. As these three phenomena, essentially distinct, reside in three organs also distinct, the possibility of abolishing any one of them, and leaving the others uninjured, seems apparent; thus the will may be destroyed, and the regulation of contraction, and contraction itself, will remain; or both volition and the regulating cause of contraction may be abolished, and contraction will alone be produced, &c.

"5. There exists therefore in the nervous system (cerebro-spinal system), three properties essentially different: one the *exciter* of motion; another the *regulator;* and the third the *willer* and *perceiver*.

"6. The spinal marrow, the medulla oblongata, and the tubercula quadrigemina, alone possess the property of directly exciting muscular contraction: the cerebral lobes and cerebellum do not possess it.

"7. There are two ways of destroying vision without going beyond the cerebral mass: one by the removal of the tubercula quadrigemina, producing loss of the *sense* of sight; the other by the removal of the cerebral lobes, causing the loss of the *sensation* of sight.

"8. There is, therefore, in the cerebral mass, distinct organs for the *senses*, for the *sensations*, for the *movements*.

"9. Not only all the sensations, all the perceptions, all the volitions, all the intellectual and sensitive faculties, reside exclusively in the cerebral lobes, but all these faculties occupy jointly the same seat in these organs; for if one of them disappear, all disappear; and if one return, all return. The power of feeling, willing, and perceiving, constitute therefore but *one* faculty, residing but in *one* organ.

"10. The cerebral lobes, the cerebellum, and the tubercula quadrigemina, may lose a considerable but limited portion of their substance without losing the exercise of their functions; and they may re-acquire them after being totally deprived of them.

"11. The spinal marrow and the medulla oblongata are the only parts which directly affect the same side of the body with that in which they are themselves affected. The tubercula quadrigemina, the cerebral lobes, and the cerebellum, alone produce their effects upon the opposite side to that in which they are influenced:—the former act in a direct course, the latter in a cross direction."

† Mr. Bell's attention was attracted by "the difference in the distribution of the nerves of the head from those of the body, and the fact that all the spinal nerves arise by double roots. Observing that this form of origin was the same in all animals possessing a spinal chord, and considering that the anterior column of the spinal marrow was continuous with the crura of the cerebrum, and the posterior with the crura of the cerebellum,—he conceived that by experiments on the roots of these nerves, he might discover the functions of the two columns, and perhaps through them arrive at a more accurate knowledge of the relations and individual uses of the cerebrum and cerebellum." Previously, however, to these experiments, Mr. Bell entertained the opinion that the anterior column of the spinal chord was different in function from the posterior, and that through the former the simple voluntary power of moving particular parts was conveyed. He deduced this from observing that the two nerves, which are generally supposed to be purely motors, arise from the anterior fasciculus. The experiments which these opinions suggested, although they were not conclusive, yet encouraged the view he had taken, and gave results in some degree similar to those which Magendie subsequently obtained

ately allotted to the performance of a distinct function,—that the posterior roots are devoted to the sensibility of the parts which these nerves supply, and the anterior to the muscular contractions. But it appears, from the experiments of M. Magendie, that one of these functions does not exclusively belong to one order of these roots; for when the posterior roots, or those which more particularly belong to sensibility, are irritated, contractions are occasioned in the muscles to which their nerves are distributed, although the contractions are much more strong and much more complete when the irritation is directly applied to the anterior roots of the nerves. Slight appearances of sensibility are also occasioned when irritation is made on the anterior roots. It must therefore be concluded, that sensibility, although chiefly, is not exclusively, in the posterior roots, nor motion in the anterior.

This defect of complete isolation of these two functions may arise, as M. Ollivier supposes, from the gray matter of each lateral half of the marrow, which seems to be concerned in their production, being entirely confounded at their central points of contact; and from the intimate union which takes place between both the roots, below the spinal enlargements (intervertebral ganglions of the posterior roots), and which must contribute still farther to combine these functions so as to prevent their perfect separation.

It should be recollected that the functions of feeling and motion ought not to be attributed to the roots of the nerves themselves. M. Magendie found, that when these nerves were divided close to the marrow, and irritation then made on their roots, no sensible effect followed; whereas, whilst their connexion with the marrow was preserved, the slightest irritation was productive of effect; and the nearer that it was made to the spinal chord, the more intense was the influence occasioned by it. Hence it follows, that the gray substance of the chord, whence arise the roots of the spinal nerves, is much more intimately concerned in the production of the operations in question than the roots of the nerves themselves; but this substance itself seems to depend more upon the different parts composing the encephalic mass, for whatever influence it may exert in the production of the phenomena under consideration, than M. Ollivier appears to allow. He attributes them both almost exclusively to the gray substance of the centre of the chord, which he considers to be voluminous in proportion as these faculties are developed. This part of the chord, although altogether necessary to, and instrumental in, their production, can only be viewed as one of three distinct classes of structure, but each of which, as M. Flourens has stated, performs distinct actions, which by their combination constitute an individual function, that could not result from any one or two only of the actions composing it, but is the consequence of a more or less perfect co-operation of the whole.*

When we consider that the fibres of the dorsal roots of the spinal nerves are larger than those of the abdominal; that the abdominal columns of the spinal chord are not altogether insensible when irritated; and that there is an intimate union between the spinal chord and the ganglial nerves, by means of branches of communication running between them and the anterior roots of the spinal nerves,—it is impossible to believe that the dorsal roots are solely destined to sensation, and the anterior roots to voluntary motion. To us it appears more accordant with the phenomena which this part of the nervous system presents in the various orders of animals, to conclude, that although these different columns of the spinal chord are more especially concerned in the performance of particular functions, yet that their functions are not strictly limited to distinct portions of the chord; and that the spinal chord is not a mere conductor of sensation and voluntary motion, but that it also aids in maintaining the vital energies of those parts to which its nerves are distributed.

On this subject we find the opinions of Dr. Spurzheim† are agreeable to our own. He conceives that the muscles or instruments of motion acquire their power in part through the influence of their nerves, whilst the will to make the muscles act resides in the brain.

The experiments instituted by Dr. Bellingeri,‡ and detailed in a memoir read before the Royal Academy of Sciences at Turin, in February 1824, do not tend to throw any new light upon this interesting subject. They confirm the idea of separate nerves of sensation and motion in the spinal chord; but they further accord motion to the nerves that issue from the dorsal roots. His inferences are, 1st, that the posterior roots of the lumbar and sacral nerves produce the motions of extension in the lower extremities; 2d, that the posterior roots alone preside over sensation; 3d, that the anterior roots produce the motions of flexion in the sacral extremities, and do not aid in perceiving external impressions; 4th, that the posterior bundles of the spinal chord preside over the motions of extension of the inferior extremities, and have no connexion with perceptions of touch; 5th, that the white substance of the spinal chord, and the nervous fibres that arise from it, are appropriated to motion; and 6th, that

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from his experiments. To Mr. Bell, therefore, the honour of having originated these views clearly belongs.

* Of the distinct functions of the *cerebellum* numerous opinions have been lately entertained. Dr. Gall considers it to be the seat of physical love. M. Rolando, who adopts the opinion of a nervous fluid, which he regards as analogous to the galvanic fluid, places the source and seat of the principle of muscular contraction in the cerebellum, which, owing to the disposition of its laminated convolutions, he considers to act in the manner of a voltaic pile, and to transmit, under the direction of the brain, and through the channel of the spinal chord and nerves, the moving principle to the muscles. M. Flourens, as we have shewn, views this organ as the regulator and balancer of the muscular contractions. M. Magendie regards it as requisite to the production of motion forwards: and Mr. C. Bell, MM. Fodéra, Foville, and Pinel-Grandchamp, are of opinion that it is the seat of sensibility.

† *The Anatomy of the Brain, with a General View of the Nervous System.* By G. Spurzheim, M.D., &c. Lond. 1826.

‡ *Bulletin des Sciences Médicales, Juin* 1825.

the gray substance of the chord, and the nervous fibres that spring from it, belong to sensation.

In opposition to the last inferences here stated, namely, that the spinal nerves may be divided into those which come from the white, and those which proceed from the gray, substance of the chord, it may be contended, that these nerves are universally implanted into the gray substance of the chord. Upon the whole, therefore, although we may grant that the columns of the spinal chord seem concerned to a certain extent in the performance of distinct functions, yet we conceive that these functions have not yet been appropriated with sufficient precision to the different parts of the chord and origins of its nerves, and that this subject stands much in need of further investigation.

Whilst the above remarks were passing through the press, M. Schœpf's experiments on the different parts of the cerebro-spinal nervous system were made known to us. These experiments shew the justice of our remarks, whilst they, upon the whole, confirm the results of those performed by M. Rolando,* M. Flourens, and Dr. Bellingeri: they are in opposition, however, to many of the inferences at which Mr. Bell and M. Magendie have arrived. They shew, moreover, that volition is entirely to be referred to the cerebral lobes; that slight irritation of the *medulla oblongata* produces convulsions, and afterwards paralysis of the same side; that more severe lesions of this part immediately arrest the movements of the respiratory organs; that the posterior as well as the anterior columns of the spinal chord, and the anterior as well as the posterior roots of the spinal nerves, are concerned in the function of voluntary motion; and that the sense of touch or sensibility belongs neither to the one nor the other.†

IV. *Of the respiratory order of nerves, &c.*—All animals that possess a perfect cerebro-spinal system have an intermediate order of nerves which connect the vegetative functions of the ganglial system with the functions of the encephalon. This order of nerves has lately been very satisfactorily examined into, both as respects their distribution and functions, by Mr. Charles Bell.

On investigating the minute structure of the nerves which, both in man and in the lower animals, arise from the spinal marrow by double roots, and those which proceed from the medulla oblongata, by single origins, to the organs of respiration, and those parts of the face and trunk which evince an intimate relation with this important function, Mr. Bell perceived that their texture and mode of distribution were very different. This circumstance led him to consider that two distinct orders of nerves must exist, independently of the sympathetic; the one simple and uniform, the other irregular and complex in proportion to the complexity of the organisation. The former he has called *original* or *symmetrical*, the latter *superadded* or *irregular*. In the superadded class of nerves, which are chiefly devoted to the function of respiration, Mr. Bell arranges, 1st, the par vagum; 2d, the portio dura; 3d, the spinal accessory; 4th, the phrenic; 5th, the external respiratory nerves, &c. "The nerves," this physiologist states, "on which the associated actions of respiration depend, and which have been proved to belong to this system, by direct experiment, and the induction from anatomy, arise very nearly together. Their origins are not in a bundle of fasciculus, but in a line or series, and form a distinct column of the spinal marrow. Behind the *corpus olivare*, and anterior to that process which descends from the cerebellum, the *corpus restiforme*, a convex slip of medullary matter, may be observed; and this convexity, or fasciculus, or *virga*, may be traced down the spinal marrow, betwixt the sulci which give rise to the anterior and posterior roots of the spinal nerves. This portion of medullary matter is narrow above where the *pons Varolii* overhangs it. It expands as it descends; opposite to the lower part of the *corpus olivare* it has reached its utmost convexity, after which it contracts a little, and is continued down the lateral part of the spinal marrow."

From this track of medullary matter on the side of the medulla oblongata, arise in succession from above downwards the *portio dura*, the *glosso-pharyngeus*, the *par vagum*, the *nervus accessorius*, the *phrenic*, and the *external respiratory*. These superadded nerves are comparatively but little sensible; they do not arise by double roots, as the symmetrical do; they have no ganglia on their origins; and while the other voluntary nerves have large, free, and round filaments, they have a close, loose texture, resembling a minute plexus. "These are the nerves which give the appearance of confusion to the dissection, because they cross the others, and go to parts already plentifully supplied from the symmetrical system."

From these anatomical investigations, and from experiments made in order to ascertain the exact functions of this order of nerves, Mr. Bell and Mr. Shaw have drawn some important inferences:—1st, They consider that the portio dura of the seventh pair "produces all those motions of the nostrils, lips, or face generally, which accord with the motions of the chest in respiration. When cut, the face is deprived of its consent with the lungs, and all *expression of emotion*. 2d, The par vagum associates the larynx, the lungs, the heart, and the stomach, with the muscular apparatus of respiration. 3d, The spinal accessory controls and directs the operations of the muscles of the neck and shoulder, in the offices of respiration. 4th, The phrenic nerve has its functions sufficiently characterised in the name of internal respiratory, which Mr. Bell has assigned it. 5th, The glosso-pharyngeal nerve, &c.; and 6th, The external respiratory nerve, perform the functions which those parts, to which they are distributed, have in connexion with the operations of respiration."

Mr. Mayo‡ subsequently investigated the functions of these nerves, and added much to our knowledge of them. He has shewn that the portio dura of the seventh nerve, and the ganglionless portion of the fifth, are simply

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* *Saggio sopra la vera Struttura del Cervello, e sopra le Funzioni del Sistema Nervoso.* Edit. 2d. vol. ii. p. 298, *et seq.*

† *Annali Universali di Medicina.* Milano, Luglio 1828.

‡ See this author's very able work, entitled "Outlines of Human Physiology." Second edition. London, 1829. Pp. 334—36.

voluntary nerves to parts which receive sentient nerves from the larger or ganglionic portion of the fifth, and that this portion of the fifth is exclusively sentient.

Mr. Broughton has also demonstrated that the portio dura of the seventh nerve, and the par vagum, are strictly nerves of motion; and he has further proved that they are entirely unconcerned in the function of sensation.*

It will be perceived, from some observations offered by us at p. 21, that we consider that the ganglionic portion of the fifth nerve is not only a sentient nerve, but that it also is engaged in the functions of secretion, exerted by the parts which it supplies, namely, the lachrymal secretion, the secretion of mucus in the nares, and the secretions of the mouth.

As far as reliance may be placed upon a single experiment lately performed by ourselves, we conceive that Mr. Broughton is perfectly correct in considering the par vagum as a nerve of motion only; and that it is in no way concerned in endowing the parts to which it is ramified with sensibility. We consider that the sensibility evinced by those parts is bestowed upon them chiefly by the visceral-ganglial nerves, which nerves are also concerned in the production of the secretions of the mucous surfaces covering the organs whose motions the par vagum actuates. As far as our own observation enables us to form an opinion, we believe that the par vagum influences the process of digestion chiefly by being concerned in the motions of the muscular coats of the stomach, thereby changing the position of its contents in respect of the villous surface, and propelling the digested portions towards the pylorus. The secreting functions of the villous surface, we believe chiefly to depend upon the ganglial nerves distributed to this organ. We further consider, that the complete division of the par vagum has impeded, or, to a certain extent, arrested, the process of digestion, owing to the acting of the muscular coats of the stomach having been thereby interrupted.

V. *Principle observed in the origin of the cerebro-spinal nerves.*—Mr. Mayo believes "that nerves of motion take their rise from the same region or segment with those sentient nerves which transmit the impressions by which their action is usually regulated. The correctness of this remark, as it respects the spinal nerves, will not be disputed. It is owing to this circumstance, that if in an animal just killed, the spinal chord be divided in the neck and in the back, on irritating the integument of either foot, that foot is retracted as promptly and to the same extent as if the spinal chord and medulla oblongata were entire.

"We observe, that the smaller portion of the fifth rises from the upper part of the medulla oblongata, close upon the greater portion; and we recollect, that the sense of pressure upon the teeth and gums, and of muscular exertion attending it, depends upon the latter, the muscular effort itself upon the former.

"We observe, that the large root of the fifth and the portio dura rise together; and we recollect that the delicate sense of touch upon the eye and eyelids depends upon the first, and the action of the orbicularis palpebrarum on the second; that the sense of touch in the nostrils depends upon the first, and the action of the muscles of the nostrils upon the second; that feeling in the lips depends upon the first, and the action of the muscles of the lips upon the second; and, finally, that the sensation of those muscles, which the second sets in action, depends upon the first.

"We observe, that the portio dura rises near the portio mollis; and we recollect, that the motions of the ear depend upon the former, and the sense of hearing upon the latter."†

These observations seem to us both correct and interesting; although this principle will not apply to every nerve of the body, as the author has candidly admitted.

VI. *General remarks on the different parts composing the nervous system.*—From what we have already advanced respecting the functions of the ganglial system of nerves, and from what has also been said respecting the other parts of the nervous system, it may be inferred that the nerves present a modified state of conformation and distribution, according to the functions which they perform. This view of the subject is confirmed not only by an attentive examination of the different nerves of the human body, but also by a comparative investigation of this part of the animal economy throughout the different classes of animals. In some of the lower orders, the organisation of the nervous system is intermediate between that of the visceral-ganglial nerves and that of the spinal nerves; and we accordingly find that nerves proceeding from the same ganglion supply both their digestive and locomotive organs. As we rise in the animal scale, nerves of an appropriate or distinct organisation and mode of distribution supply particular organs, and discharge specific functions. It was not until the time of Winslow that this principle in the animal economy seems to have been sufficiently recognised. He first distinguished between the ganglial nerves and those of the cerebro-spinal system. This division was afterwards adopted by Johnstone, Bichât, and some other anatomists. But a more attentive examination will shew, that the nervous systems may be still further divided. The ganglial system of nerves may, we conceive, be subdivided,—1st, into the ganglial nerves supplying the viscera; and 2dly, into the ganglial nerves of association, or those which communicate between the first division, or visceral nerves, and the cerebro-spinal nervous system.

This latter system may be subdivided into, 1st, the brain proper; 2d, the cerebellum; 3d, the medulla oblongata and spinal chord; 4th, the nerves of sensation; and 5th, the nerves of motion.

Although it seems evident, from the experiments of Mr. Bell, Mr. Magendie, Mr. Mayo, Mr. Broughton, and Dr. Bellingeri, that the nerves perform distinct functions, yet we conceive that those functions have not been assigned with sufficient precision to their respective nerves. Indeed, the imperfect state of our knowledge has not allowed this to be done in a way at all accordant with well-ascertained phenomena. Many of the nerves, also, seem to perform more functions than one: thus the ophthalmic branch of the trigeminal nerve sup-

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* Medical and Physical Journal for June 1823, p. 463.

† *Outlines of Human Physiology.* By H. Mayo, F. R. S., &c. 2d Edit. Pp. 343, 344.

plies the lachrymal gland, and presides over its secreting functions; filaments proceeding from the same branch supply the iris, are instrumental in its motions, and seem to preserve the eye in a fit state for the performance of its delicate functions: the nasal portion of the nerve seems to be concerned in both the secretions and sensations of the organ; and the third branch of the same nerve appears to perform similar offices in respect of the organ of taste. We know that some of the ganglial nerves of the thorax and abdomen are chiefly instrumental in the production of the insensible motions of the contractile organs which these cavities contain, whilst others of these nerves preside chiefly over the functions of the secreting viscera. Yet these nerves, whether those engaged in endowing contractile organs with the power of motion, or those presiding over the functions of secretion and sanguification, &c. also possess the faculty of conveying sensations, and are evidently possessed of variously modified sensibilities. How far these latter properties depend upon the associating ganglial nerves, or those which communicate between the cerebro-spinal system* and the visceral ganglial system,† our researches have not enabled us to determine: but, from the examinations we have already made, we conceive that this associating order of nerves performs a very important part in conveying to the visceral-ganglial system of nerves the nervous energy of the spinal chord and medulla oblongata, in connecting the functions of the different nervous masses, and in transmitting the peculiar sensations excited in any of the viscera of organic life to the brain.

In the first edition of these Notes we stated fully our opinions as to the functions which the ganglial system of nerves performs in the animal economy. These opinions were mistaken by one or two writers who soon afterwards noticed them, and who confounded them with the opinions which had been entertained respecting these nerves by previous writers, especially with those of Bichât. His opinions respecting them were, in many respects, the same as those espoused by Sœmmering and by Reil; and whoever has attentively read the "Anatomie Générale," and the writings of the German anatomists, previous to perusing the note on the functions of ganglial nerves, at p. 12, *et seq.*, will perceive in what we have differed from, or agreed with them; and how much farther our inferences have been carried than those at which these great physiologists had arrived.‡

OF THE PHENOMENA OF MIND AS MANIFESTED THROUGH THE INSTRUMENTALITY OF A PERFECT NERVOUS SYSTEM.

(Notes H H. See pp. 251—261.)

The manifestations of mind have engaged the researches of some of the most acute inquirers who have "interrogated nature" during the last half century. Their progress, however, in this very interesting and difficult field, has not been equal to the growing zeal with which it has been cultivated. This want of success is, in our opinion, much less to be imputed to the individuals who have engaged in the inquiry, than to the obstacles which beset a subject that involves the mysterious union of mind with matter, and which holds relations with both of the most intimate nature; and under aspects of apparently the most contradictory character.

The operations of a system possessing so extended a connexion between the intellectual faculties on the one hand, and the corporeal functions on the other, and reciprocally receiving and communicating influence during health and disease, cannot be accurately traced, even in the more evident phenomena, without a considerable degree of patient observation and research. There, however, exist many subtle relations, which require a still more laborious demonstration; and which, when admitted, are explained with greater difficulty and doubt. These have always afforded materials for various and conflicting hypotheses, which, while they have saved us from secure and happy ignorance, have roused us to a more eager search after truth. Notwithstanding the number of theories that have consequently abounded, and the impulse they have given to human intellect, many humiliating considerations must obtrude themselves, when we meditate upon the conclusions to which some of them have led, and upon the slow progress that

* The nervous system of sensation, volition, and of the mental manifestations.

† The nervous system of organic or vegetative life.

‡ We may remark, by the way, that Johnstone, Bichât, Sœmmering, and Reil, conceived that the ganglia of the great sympathetic interrupt the reciprocal influence of the cerebro-spinal nervous system, and the viscera of the large cavities. Now, this is evidently not the fact, because this nerve, through the means of its various connexions, actually conveys sensations and impressions, made upon these viscera, both in health and in disease, to the brain, as well as transmits the energies of the brain and spinal chord of the perfect animals, to reinforce the appropriate functions of the visceral-ganglial nerves. Besides, if we examine the organisation of those nerves which are now proved to be chiefly engaged in the function of sensation, we shall find that they all possess a soft texture, and have ganglial enlargements near their origins; so that ganglia do not interrupt the functions of sensation, although they may modify the sensation, and are perhaps adapted to the conveyance of certain impressions in preference to others; and we may, moreover, add, that ganglia are chiefly important in interrupting the transmission of volition, and of the impressions, passions, and affections of the mind, to the viscera more immediately related with life, and thus preventing the bad consequences which would result from the dominion of the cerebro-spinal nervous system over the vicera of organic life. Indeed, we perceive, that when a nerve presents a soft consistence, and is connected with a ganglion, it is not a nerve of volition, or the medium through which the will changes the condition or position of a part, although it may be a nerve of sensation, and performing either this function alone, or that of secretion, or some other action in addition.

has been made towards advancing our knowledge respecting the cerebral functions in relation both to the mental and corporeal manifestations. How little has been added to the strictly physiological department of this subject, to what may be found in the writings of Galen! and what has the science of mind gained, during so many centuries, from the contending followers of Plato, Aristotle, and Epicurus, beyond the dawn of reason which had already appeared in their discordant theories?

It certainly cannot be wondered at, that human intellect has wandered upon an ocean of uncertainty respecting its own operations, and those corporeal functions with which it holds so intimate a connexion, when it is considered, that until the end of the last century but little care was taken to collect and arrange a requisite number of facts, and to direct the mind to a careful observation and analysis of the extent and nature of its faculties. Until our own times, how little anxiety have the majority of philosophers shewn to ascertain the stability and connexion of the data upon which they founded their doctrines; and which often led, from the neglect of that precaution, to conclusions irreconcilable with common sense and the experience of our senses!

The philosophy of Bacon, which, in this country at least, has extended its influence to the science of mind, promises to advance this department of human knowledge; and by teaching the necessity of attending with more precision to the relations of our various mental emotions, to the objects of our consciousness, and to the origin and history of our ideas, whether those which are derived from our senses or from reflection, to guide our speculations through an inductive chain to conclusions more correct, and certainly more ennobling, as they regard human nature, than many that have been adopted in modern times.

The metaphysical system of Kant has tended in no small degree to retard this advancement throughout a great part of the continent; and, although it is indebted to Cudworth for its better parts, it appears to have given a wrong impulse to the science of mind; and thus have arisen the mystifications of Fichte and of Schelling, now so generally adopted over Germany; and which, most probably, will enjoy as short a dominion as that of their predecessor.

It has been urged by all the favourers of Epicureanism, and by many of the followers of Gassendi and Hobbes,—but more especially by Priestly, Buffon, Darwin, Maupertius, Blumenbach, Cabanis, Lawrence, and by others of the modern French school of materialism,—that, as the manifestations of mind are never met with, unless connected with a brain, or are suspended by compression of this organ, so the phenomena generally attributed to it are the result of the organisation of the nervous fabric. All these philosophers do not distinctly enunciate this proposition; but the general tendency of their doctrines leads to its adoption. That any combination of the molecules of matter can produce the various powers of mind, is a paradox which they generally evade, but cannot explain. If this principle proceed from certain associations of organic particles, why is not some probable opinion respecting this process given? Does our experience respecting the mutual influence of either the elements or the aggregate of matter furnish us with resulting phenomena, that can in any degree approach to the lowest manifestations of either vitality* or mind? If it be derived from the combination of these particles, or from the operation of certain of their products upon each other, is it possible to conceive that matter, in such a state, possesses qualities, of which the elements or even the individual atoms are divested? If, on the other hand, properties necessary to the generation of the mental faculties be conceded to every particle entering into the formation of the encephalon, how can the idea of the subdivision of the powers of mind, to such an extent as matter, be admitted? Can the supposition be for a moment entertained, that every molecule of this admirable organ has a fractional part of mind connected with it? † Many of the materialists,

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* See Note A of this Appendix.

† Since the above remarks were first published by us (in 1822), the doctrine of materialism has been ably opposed by Dr. Barclay, (An Inquiry into the Opinions, Ancient and Modern, concerning Life and Organisation. By John Barclay, M.D. &c. &c.) and by Dr. Thomas Brown, in his Lectures, which have been recently printed. "In whatever manner, therefore," it has been argued by the latter able metaphysician, "the materialist may profess to consider thought as material, it is equally evident, that this system is irreconcilable with our very notion of thought. In saying that it is material, he says nothing, unless he means that it has those properties which we regard as essential to matter; for, without this belief, he might as well predicate of it any barbarous term that is absolutely unintelligible, or rather might predicate of it such a barbarous term with more philosophic accuracy; since, in the one case, we should merely not know what was asserted—in the other case we should conceive erroneously that properties were affirmed of the principle of thought, which were not intended to be affirmed of it. Matter is that which resists compression, and is divisible. Mind is that which feels, remembers, compares, desires. In saying of mind that it is matter, then, we must mean, if we mean any thing, that the principle which thinks is hard and divisible; and that it will be not more absurd to talk of the twentieth part of an affirmation, or the quarter of a hope, of the top of a remembrance, and the north and east corners of a comparison, than of the twentieth part of a pound, or of the different points of the compass, in reference to any part of the globe of which we may be speaking. The true answer to the statement of the materialist, the answer which we feel in our hearts, on the very expression of the plurality and divisibility of feeling, is, that it assumes what, far from admitting, we cannot even understand; and that, with every effort of attention which we can give to our mental analysis, we are as incapable of forming any conception of what is meant by a quarter of a doubt, or the half of a belief, as forming to ourselves an image of a circle without a central point, or of a square without a single angle." (*See Lectures on the Philosophy of the Human Mind.* By the late Thomas Brown, M.D., Professor of Moral Philosophy in the University of Edinburgh. 8vo. Edinburgh, 1828. pp. 646.)

in order to account for the operations of this principle, had recourse to so many suppositions respecting the nature and endowments of matter, either in respect of its elements or aggregate, as were tantamount to a negative admission of the agency of life; with this notable difference, however, that they required the operation of more numerous agents, instead of the more philosophical doctrine that referred them to states of this first and noblest constituent of our nature. The genius of Leibnitz saw the difficulty that stood in the way of pure materialism, and in order to give his passive atoms activity, and origin to the mental phenomena, he had recourse to the ἐντελεχειαι, or spirits, of Aristotle.

The French physiologists, with Cabanis at their head, adopted the doctrine of organism; and in order to supply the want of a foundation to their structure, they seized with avidity upon the opinions of Gassendi respecting the origin of our ideas. Their theory still required support; and in order that it might receive such from a name looked to with deference throughout Europe, they unjustly imputed to Locke doctrines which were derived from the two celebrated opponents of Descartes already mentioned. Much of the credit which this system acquired in France and in the north of Germany, arose also from the neglect with which that class of our ideas derived from reflection was uniformly treated. The writings of Locke, Cudworth, Price, and others, directed attention to this highest principle of our nature, and, in part, gave origin to the system of Kant; which, like the physiology of Gall and Spurzheim, promulgated so soon after the philosophy of their countryman, was indebted to some acknowledged truths, mixed up with many assumptions, for the partial credit which it has obtained. Indeed, the doctrines of these systematists are more closely allied than has been generally supposed; and it is not unlikely that the opinions of Gall were, in a great measure, derived from the *Critique of Pure Reason.* How far these systems, especially that of Gall, may lead to Spinozism, we cannot here inquire. We would recommend the writings of Cudworth, Price, Reid, Stewart, Barclay, and Brown, especially those of the three last-named authors, to those who are inclined to satisfy themselves more fully as to the arguments which may be adduced in proof of the independent existence of mind, and who wish to guard against the seductions to Phyrronism contained in the writings of Montaigne, Berkeley, and Hume.

Our remarks on this very extensive subject, were we to pursue it further, could only be cursory, and therefore would necessarily appear to many both desultory and unsatisfactory. We shall merely, therefore, offer a classification of the manifestations of mind, commencing with the lowest, or those most extensively disseminated throughout the animal kingdom, and proceeding to the highest or more perfect faculties.

CLASS I. INSTINCTIVE FEELINGS AND EMOTIONS.—(Strong and immediate Incentives to Action.

- ORDER I. *Instinctive feelings which tend to preserve the Individual.*
  - 1. The Sensations. 2. Volitions or Desires. 3. The Appetite for Food and Drink. 4. The Desire of preserving the Animal Warmth. 5. The Desire of Repose. 6. Desire of Place. 7. Desire of continued Existence. 8. Desire of Pleasure, and Dread of Pain.
- ORDER II. *Instinctive Feelings which tend to perpetuate the Species.*
  - 1. The Appetite for Procreation. 2. Parental and filial Affection. 3. Desire of Society. 4. Social Affection, giving rise to mutual support.
- ORDER III. *Instinctive Emotions of Mind, tending to promote the chief Objects of our Existence;* (and, with the former orders of this class, entering more or less as ingredients into all the Intellectual and Moral Manifestations of Mind.)
  - 1. Gratitude. 2. Anger. 3. Pride, Humility. 4. Gladness, Regret, Sadness. 5. Wonder, Desire of Novelty, Mental Languor. 6. Beauty and Deformity. 7. Sublimity and Ludicrousness. 8. Sympathy. 9. Love and Hate. 10. Love of Approbation. 11. Desire of Knowledge. 12. Desire of Power.

CLASS II. INTELLECTUAL POWERS, OR STATES OF MIND.

- ORDER I. *Powers of Consciousness, or the simpler Intellectual States of Mind.*
  - 1. Perception. 2. Attention. 3. Conception. 4. Memory.
- ORDER II. *Powers of Intellection, or the more Active Intellectual States of Mind.*
  - 1. Association of Ideas. 2. Abstraction. 3. Imagination. 4. Judgment or Reasoning.
- ORDER III. *Ideas of Reflection, springing from the Exercise of the former Orders of Powers.* (Rational Incentives to action.)
  - 1. Mental Identity. 2. Time. 3. Power. 4. Truth, Causation. 5. Right and Wrong. 6. Existence of a Deity. 7. Immortality of the Soul.

CLASS III. MORAL AFFECTIONS OF MIND. (In which our *Instinctive Feelings* and *Emotions*, as well as our *Intellectual Powers*, are frequently more or less engaged, and which are deliberate, rational, and often strong incentives to action.)

1. Duty, Rectitude, Virtue, Merit and Demerit, with all our moral Obligations, Emotions, and Desires, in our various relations to society, &c. 2. Religious Obligations, &c. 3. Duties we owe ourselves, and which tend to promote our Intellectual and Moral Excellence and Happiness, &c.

It will be perceived that the third order of ideas into which we have here arranged the intellectual powers, are chiefly derived from reflection, or from the mind itself.*

The above arrangement exhibits merely a general outline of the phenomena of the human mind. It does not contain every collateral or subordinate affection, particularly several of those which belong to the first and third classes, into which we have divided the mental manifestations. It may be remarked generally, that sensation, and volition or desire, are the most widely diffused throughout the animal kingdom, of all the states of mind; and that although we have assigned perception, attention, memory, and conception, more especially to consciousness, we consider that this state of mind is not distinct in itself, but the concomitant of these and all the other manifestations of the human mind. Perception is a sensation of which we are presently conscious. Memory is the suggestion of sensations of which we were formerly conscious, and of whose present suggestion we are now conscious. Conscientiousness is the attendant on both attention and conception, in a similar manner as in respect of the other two mental states; for attention is continued or repeated perceptions, and conception is only a more definite act of memory, proceeding from the influence of volition or desire upon our present or our former sensations. Consciousness, although thus intimately related to these particular states of mind, is also the concomitant of all our present mental emotions and manifestations: it is the present state of mental existence, whatever that state may be; it indicates the mind's unity and the mind's identity: hence it has attended on all our mental feelings, actions, and passions; does attend them; and will attend those which shall take place at a future period.

Of the instinctive principles of mind, which we have made the first, because the most generally diffused, class, and especially of the first and second orders placed under it, we shall merely remark, that they guide the operations of animals in a uniform manner; that similar instinctive actions and feelings manifest themselves uniformly in all the individuals belonging to the same species; that they lead to determinate ends with unerring certainty, prior to all experience; and that they are far superior, as incentives to action, to all the manifestations of reason of which the lower animals are possessed. Even in man, the instinctive feelings when indulged in, and strengthened by habit, become too powerful for our reason; and although man is characterised by his reason being superior to his instinctive emotions, yet the latter not infrequently obtain the ascendancy, when their dictates are blindly followed, and when the intellectual and moral principles of our minds have not been duly cultivated. The instincts of the lower animals are scarcely ever controlled by the manifestations of reason which they evince; although a few exceptions to this occasionally appear in respect of a few animals which have been domesticated with man.

Our limits will not permit us to controvert the opinions of Locke, Berkeley, Hume, and Condillac, who denied the existence of any instinctive feelings in the human mind; — but it is evident, from a careful analysis of the different phenomena of mind, that, in addition to the instinctive feelings we possess in common with the lower animals, we are originally endowed with various mental emotions of a higher nature than those which they manifest, and which, independently of the ideas we acquire by means of reflection, and the numerous class of our moral emotions, desires, and duties, evince that we possess a somewhat differently constituted, as well as a more advanced state of mind. Of this kind are those instinctive emotions which we have arranged in the third order of the first class of the above classification of the mental powers, as well as the whole of our moral affections.†

The doctrines of Gall.—The anatomy of the

* See on this subject the writings of Dugald Stewart; the published Lectures of Dr. Brown; Dr. Barclay on Life and Organisation; Dr. Prichard on the Nervous System; and the London Medical Repository, vols. xvii. and xviii.

† We subjoin the following analysis of the physiology of mind, according to the very able and original views of Dr. Thomas Brown, whose early death must be a matter of regret to all lovers of metaphysical inquiries and of the *belles letters*.

CLASS I. EXTERNAL AFFECTIONS OF MIND; arising from the presence of objects external to the mind itself.

ORDER I. *Simple External Affections of Mind.* The Sensations derived by the Organs of Smell, Taste, Hearing, Seeing, Touch, Muscular Action, Pleasure, Pain, &c.

ORDER II. *Complex External Affections of Mind.* Sensation accompanied by simple Suggestion, is *Perception.* Perception with Desire, is *Attention.*

CLASS II. INTERNAL AFFECTIONS OF MIND; proceeding from previous Change in the States of the Mind itself, in consequence of the Laws of Thought and Feeling.

ORDER I. INTELLECTUAL STATES OF MIND.
GENUS I. *Simple Suggestion.* (Association.) Primary Laws of.—1. Resemblance.

nervous system has been greatly indebted to this very indefatigable and eminent inquirer; and to whatever credit his doctrines may be found entitled, it cannot be denied that the science of mind has already been somewhat benefited, although indirectly, by the opinions he has promulgated, and which have at least been ingeniously supported by his followers. As to the doctrines themselves, we will not give any opinion: if we were inclined to do so, what we could offer respecting them would not be favourable to them in all their details, although we might admit that some of their fundamental principles seem based on truth. The favourers of craniology appeal to facts, assert that it is eminently a science of observation and rational induction, and call upon those who oppose it to make themselves acquainted with its principles and details, and then observe and judge for themselves. This seems candid and rational; but, unfortunately, when their advice is followed, and facts are observed which militate against their theory, they endeavour to rid themselves of the difficulty by asserting that the observer is mistaken, and unacquainted with its principles,—thus virtually denying that any one

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2. Contrast. 3. Nearness in Place or Time.

Secondary or Modifying Laws of.—
1. Duration of the original Sensation. 2. The Liveliness of the Sensation. 3. The Repetition or Renewal of the Sensation. 4. The Recentness or Remoteness of the Feeling. 5. The Feeling having co-existed but little with other Feelings, or only with one or two Feelings. 6. They vary according to original Constitutional Differences. 7. According to Differences of Temporary Emotion. 8. According to Changes produced in the State of the Body. 9. According to general Tendencies produced by prior Habits.

Forms of Simple Suggestion.
A. *Conception*, merely a more special Suggestion.
B. *Memory* is merely Suggestion combined with the Feeling of a Relation of Priority to our present Consciousness.
a. Memory combined with *Desire* is *Recollection*.
C. *Imagination*.
a. A Mode of simple Suggestion, or a momentary grouping of Images, independently of Choice or Desire.
b. Groups of simple Suggestion in union with Desire, or Conception following Conception at Desire.
D. *Habit*, or the frequent Repetition of any Action or Train of Suggestions.
a. As producing a greater Tendency to Actions or Trains of Suggestion.
b. As occasioning greater Facility and Excellence in those particular Actions.

GENUS II. *Relative Suggestion.*
SPECIES I. Co-existent Relative Suggestion, or Relations of Co-existence. A. In respect of Position. B. In respect of Resemblance or Difference. C. Of Degree. D. Of Proportion. E. Of Comprehensiveness, or the Relation of a Whole to its separate Parts.
SPECIES II. Successive Relative Suggestions, or Relations of Succession, or Relations involving the Notion of Priority and Subsequence. A. Casual Relations of Succession. B. Invariable Antecedence or Consequence.

Forms of Relative Suggestion.
A. *Judgment.*
B. *Reasoning.*
C. *Abstraction.*

ORDER II. EMOTIONS OF MIND.
When excited by External Objects, are excited only indirectly and through the Medium of Sensation.
They differ from the Intellectual State of Mind by the peculiar Vividness of Feeling accompanying them.

GENUS I. *Immediate Emotions.*
SPECIES I. Immediate Emotions involving no Moral Affection. A. Cheerfulness, Melancholy. B. Wonder, Novelty, &c.; Languor, from the same Succession of unvaried Feelings. C. Beauty, and its reverse. D. Sublimity and its opposite, Ludicrousness.
SPECIES II. Immediate Emotions, in which Moral Feeling is necessarily involved. A. Feelings distinctive of Vice and Virtue. B. Emotions of Love and Hate. C. Sympathy with the Happiness and Sorrow of others. D. Pride and Humility.

GENUS II. *Retrospective Emotions.*
SPECIES I. As they relate to Others. A. Anger, Gratitude.
SPECIES II. Having direct reference to ourselves.
A. Simple Regret and Gladness, arising from Events we cannot control. B. Moral Regret and Gladness, arising from our own Actions.

GENUS III. *Prospective Emotions;* comprehending all our Desires and Fears. Wish, Hope, Expectation, Confidence, are different Forms of Desire.
SPECIES I. Desire of continued Existence. 2. Desire of Pleasure. 3. Desire of Society. 4. Desire of Knowledge. 5. Desire of Power. A. Direct Power, as Ambition. B. Indirect Power, as Avarice. 7. Desire of the Affection of those around us. 8. Desire of Glory. 9. Desire of the Happiness of Others. 10. Desire of the Unhappiness of those we hate.

can be acquainted with their doctrines unless he be likewise a convert to a belief in them. When, however, pressed by facts which seem irresistible, they have so many ways of eluding the difficulty between their ideas respecting the activity and volume of the particular organ in question, or the developement and activity of controlling, of opposing, and of co-operating organs, that there is an end of all argument. The numerous treatises which have appeared upon this subject render it unnecessary for us to enter more particularly into details respecting it. We should, however, be guilty of a neglect of duty were we to refrain from recommending to the perusal of the candid and inquisitive reader the last and greatest work of the celebrated originator of the doctrine in question.* We have seldom been more interested than we were by the perusal of this work, although it failed of converting us to a belief of the doctrines which it inculcated.

In order to give the reader an idea of the opinions of this able author in as succinct a manner as possible, we need only quote the following condensed translation contained in the learned notes of Dr. Elliotson, one of the most learned and indefatigable supporters of craniology in this country.

"The exact situation of the organs can be learnt from drawings or marked heads only. I shall, therefore, confine myself to remarking: —1st, That the organs of the faculties or qualities common to man and brutes are placed in parts of the brain common to man and brutes, —at the inferior-posterior, the posterior-inferior, aad inferior-anterior parts of the brain; *v. c.* of the instinct of propagation, the love of offspring, the instinct of self-defence, of appropriating, of stratagem, &c. 2dly, Those which belong to man exclusively, and form the barrier between man and brutes, and placed in parts of the brain not possessed by brutes, viz. the anterior-superior and superior of the front; *v. c.* of comparative sagacity, causuality, wit, poetic talent, and the disposition to religious feelings. 3dly, The more indispensable a quality or faculty, the nearer are its organs placed to the base of the brain or median line. The first and most indispensable, the instinct of propagation, lies nearest the base; that of love of offspring follows. The organ of the sense of localities is more indispensable than that of the sense of tones or numbers; accordingly, the former is situated nearer the median line than the two latter. 4thly, The organs of the fundamental qualities and faculties which mutually assist each other, are placed near to each other; *v. c.* the love of propagation and of offspring, of self-defence and the instinct to destroy life, of tones and of numbers. 5thly, The organs of analogous fundamental qualities and faculties are equally placed near each other; *v. c.* the organs of the relations of places, colours, tones, and numbers, are placed in the same line, as well as the organs of the superior faculties, and the organs of the inferior propensities.†"

Of Dreaming.—Mr. A. Carmichael has lately adopted and illustrated the theory of dreaming proposed by Dr. Spurzheim, that dreams are caused by certain isolated portions or organs of the brain continuing awake, while the remainder of it is in a temporary paralysis from sleep. "According to this view, the particular dream will be fashioned by the part or parts which are not under the dominion of sleep; and the irrationality of our sleeping thoughts is accounted for by one or more parts or organs thus acting without co-operation or correction from the other parts of the encephalon."

Mr. C. enumerates no fewer than *seven* different states of sleeping and waking:—*When the entire brain and nervous system* are buried in sleep,—then there is a total exemption from dreaming. 2. *When some of the mental organs are awake and all the senses are asleep*,—then dreams occur, and seem to be realities. 3. When the above condition exists, and the *nerves of voluntary motion* are also in a state of wakefulness,—then may occur the rare phenomenon of somnambulism. 4. *When one of the senses is awake, with some of the mental organs*,—then we may be conscious, during our dream, of its illusory nature. 4. When *some of the mental organs are asleep, and two or more senses awake*, —then we can attend to external impressions, and notice the gradual departure of our slumbers. 6. When we *are totally awake*, and in full possession of our faculties and powers. 7. When, under these circumstances, we are so occupied with mental operations *as not to attend to the impressions of external objects*; and then our revery deludes us like a dream.

OF THE FORMATION AND DEVELOPEMENT OF THE MUSCULAR STRUCTURE, AND OF THE SOURCE OF IRRITABILITY.

(NOTE I I. See pp. 270—273, 280.)

In the very lowest orders of animals, a muscular structure does not exist in a distinct state. Their partial movements are performed by means of the cellular tissue of which they are composed. In the lowest of the series possessing a muscular texture, it moves only the integuments to which it is attached, and of which it even forms a part. In all animals possessed of a heart the muscular tissue constitutes an important part. In all the vertebrated animals a small number only of the muscles are attached to the mucous surfaces, to the skin and its appendages; whilst the greatest proportion is connected with the skeleton, for the purposes of progression.

According to the researches of Dr. Isenflamm, of Dorpat, into the progressive developement of the muscular structure in the human fœtus, this tissue is formed from the mucous and gelatinous fluid of which the embryo is at first composed.

From this mucous fluid the involuntary muscles are first developed, and afterwards the voluntary. During the first three months the voluntary muscles present the appearance of viscous layers, with a slight yellowish tint. At the end of the third month the tendons make their appearance. During the fourth and fifth months the muscles become redder, more fibrous,

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* *Sur les Fonctions du Cerveau.* Par F. J. Gall. tom. 4, 8vo. Paris, 1825.

† *Gall sur les Fonctions du Cerveau*, tom. iii. p. 208 *et seq.*: and Dr. Elliotson's Notes to his Translation of Blumenbach's Physiology, p. 209.

and more easily to be distinguished from their tendons. In the sixth month, although very soft, they are still more perfect. At the full term of utero-gestation the muscles are formed, but they are pale, yet vascular: they are soft, and their bulk much greater in proportion to the tendinous and aponeurotic substances than in the adult.

As age advances, the voluntary muscles become redder and more fully developed; and towards the decline of life, more rigid, less capable of quick and extensive contraction, and comparatively of less bulk than their aponeurotic and tendinous connexions.

The microscopic observations of Mr. Bauer, Sir Everard Home, MM. Prevost, Dumas, and Beclard, seem to prove that the ultimate muscular fibre is composed of corpuscles (arranged like a string of beads) in every respect similar to those in the centre of the red globules of the blood. However, to obtain a correct idea of the ultimate conformation of the muscular fibre, researches ought to be made with this view on the raw and unprepared muscle; for the action of heat, of alcohol, and acids, evidently produces changes in the fibre, and coagulates the albumen which enters into its composition.

The voluntary nerves dip into the texture of the voluntary muscles at different points, and divide into numerous minute fibriles, which abruptly escape demonstration. This sudden manner of disappearing is owing to the extreme fibriles having become soft and diaphanous, and deprived of their proper envelopes, so that their medullary substance is diffused, as it were, into the mucous tissue, connecting the muscular fibres.

The cerebro-spinal nerves, although they are numerous and large in the voluntary muscles, disappear in the manner just pointed out, long before their divisions become sufficiently numerous to be distributed to each muscular fibre. This being the case, how can the action of these nerves on *all* the fibres be explained? They cannot be the *direct* cause of the muscular contraction, but must act in producing it through the medium of another and a more general conformation. What this formation appears to us to be, we will now endeavour briefly to shew.

It has been stated that all the involuntary muscles are supplied with the ganglial or soft nerves only; that they surround the arteries throughout their ramifications, and consequently are thus present in the voluntary muscles and in all vascular parts; that the voluntary nerves themselves, whether we trace the process of their formation in the human embryo, or observe them in the lower orders of animals, seem to originate from the ganglial, the cerebro-spinal masses being the perfection of the nervous conformation, and the last part of it which becomes completely developed; and that the cerebro-spinal nerves are destined to the performance of functions distinct from those to which the other and more generally diffused class is allotted. As irritability is present in parts which do not receive voluntary nerves, and in animals which do not possess this part of the nervous system, this property cannot be attributed to it. To what other species of organisation can we refer this property? We find it, in the more perfect animals, chiefly displayed by the muscular structure. Is it from this circumstance an attribute of muscular parts, and the pure result of their conformation? One class of physiologists answer this question in the affirmative. But irritability is displayed by the lowest orders of the animal creation, wherein a muscular structure cannot be detected, even in the parts themselves which furnish the phenomenon; therefore, although a property of the muscular fibre, it is neither altogother restricted to it, nor is it strictly the result of the organisation of the fibre itself. We must, consequently, refer this property to a conformation still more general than the muscular tissue, both as respects the whole scale of the animal creation and the organisation of individual species; allowing, at the same time, that a particular structure is requisite to the full and perfect developement of this property, but that this structure depends upon a different source than itself for the property which it displays.*

Having arrived at the conclusion, that irritability, although a property of muscular parts, is not the result of muscular organisation, but is derived from a different and more general system, supplying the muscular structure as well as other structures, we must next inquire what this system is. It has been already inferred, from various considerations, that the ganglial class of nerves is distributed in different proportions to the various textures and organs of the body; that these nerves are similarly distributed throughout all the individuals composing the animal kingdom; that in some of its orders they constitute the only nervous system which the animal possesses: it has also been demonstrated that this class of nerves, in a more or less perfect state of organisation, is present wherever irritability is manifested; that these nerves are the most generally diffused of any of the animal tissues; that no other structure exists but this which can be shewn to be present in every species of irritable parts, in all orders of animals; and, consequently, that to no other source but this can the property of irritability be assigned.

Having inferred that this muscular fibre is only the instrument of contraction in its more perfect condition,—that it performs this function in consequence of a certain conformation, and owing to that conformation being endowed by means of another still more generally diffused than itself,—and that this property is derived from the ganglial or soft nerves, which proceed, either directly or as an envelope to the arteries, to all the tissues of the body,—we are led far-

* We have perceived, as the above sheet was passing through the press, that the identical opinions which have been insisted upon by us, both in the former edition of these Notes, and in several numbers of the Medical Repository for 1822, respecting the functions of the ganglial nerves, have been recently espoused by M. Adelon in his System of Physiology. Our opinions on these subjects will be found stated succinctly in the copious notes contained at pp. 12—16 and p. 15 of the present impression, and without the smallest addition to, or alteration from, what is to be found in the first edition of this Appendix, which was published in the beginning of 1821. For M. Adelon's observations on these subjects, we refer to his *Physiologie de l'Homme*, tome iv. (the first edition of which appeared at the commencement of 1825,) *seconde édition*, p. 146, *et seq.* Paris, 1829.

then to infer that the cerebro-spinal nerves are distributed to muscular parts for specific purposes, but that these parts do not derive their innate properties from these latter nerves—these nerves merely excite them, or rather are conductors of a stimulus acting on properties which proceed from a different source. We have contended that these properties are not innate, or the consequence of the conformation of the muscular fibre itself; but are derived from a conformation still more general, which surrounds or is otherwise connected with the muscular fibriles, and that this more general conformation is the ramifications of the ganglial class of nerves. Conceiving, therefore, that these nerves in their state of ultimate distribution and dissemination in the texture of the muscle, whether in the form of unarranged globules, or of minute and variously arranged fibriles resulting from the regular distribution of these globules, are the chief source of the property evinced by muscular parts of every denomination, we further conclude that the voluntary or cerebro-spinal nerves do not produce their specific effects on the muscular fibres, owing to a nervous fibrile being ramified to each muscular fibrile, for this does not take place; nor do these effects proceed from the direct influence of these nerves upon the muscular fibrile, for the muscular fibre derives its property or faculty of contraction from a source different from itself and from the voluntary nerves which occasionally excite its contractions; but that these nerves seem to act directly upon the ultimate distribution of the ganglial nerves of the muscle, which latter nerves bestow on it the faculty of, or the disposition to, active contraction, on the application of a stimulus, which faculty all muscular parts possess,—the former class of nerves conveying to some of these parts only the natural stimulus which induces contraction, or which excites the active exertion of this faculty bestowed on these parts from a different source, namely, from the ganglial system. The mode of termination which the voluntary nerves observe in muscular parts, also favours the opinion which we have now given. These nerves terminate, as we have already noticed, in such a manner as leads us to infer, that they become, in the textures which they supply, gradually identified, as it were, or amalgamated, with the ultimate distributions of the ganglial nerves: and the history of the embryo, and the progressive developement of the nervous system in the lower animals, dispose us to believe that the voluntary nerves originate in the textures which they supply; that they proceed from the ganglial system; and that their larger branches, the spinal marrow, and encephalon, are successively formed.*

OF GALVANIC ELECTRICITY.

(Note K K. See pp. 285, 286.)

The phenomena of electricity have been long known to philosophers; but science has been chiefly indebted, in our own times, to the researches of Davy, Woollaston, Biot, Coulomb, Poisson, Oersted, and Becquerel, for a knowledge of the laws by which it is characterised. The observations and experiments of these successful inquirers appear fully to warrant the conclusion, that this very active agent of nature results from two distinct fluids universally diffused through every species of matter. During their circulation, in their electro-motive capacity, through the corpuscles of matter forming the crust of this planet, they accumulate in their free and uncombined state upon its external surface, in consequence of the imperfectly conducting property of the enveloping atmosphere.

The electricities "are thus confined on the superficies of the globe, and indeed of all bodies placed on its exterior, not merely by the non-conducting faculty of the air, but also by a species of mechanical pressure which the air exercises." Hence arise the electrical phenomena which so frequently become the objects of observation.

In elevated situations, in experiments where the density of the air is exhausted and the aërial particles rendered fewer in number, and in other favourable circumstances of the atmosphere, as in its humid state, the electric power emanates with rapidity from the electrised ball.

Such is the mode of existence of this fluid upon the surface of the earth. But there also exists a continual condensation of the electrical agencies in the substance of the different matters composing the crust of this planet; and the galvanic, chemical, and other phenomena, clearly shew that although such condensation of the electricities takes place under particular circumstances of matter, yet a continuous circulation of it is also evident under other relations. This, indeed, is observed to occur during every manifestation of the galvanic influence.

Such then being the case, and as it is now generally believed that the circulation of the electricities through the atoms of matter, or the electro-motive state, as it has with propriety been called, gives rise to the phenomena of galvanism,† which, within these few years, has led to the most splendid discoveries in the physical world,—is it not reasonable to suppose that similar operations to those with which galvanic experiments make us acquainted, are continually taking place in the elements of nature? As it has been shewn that every species of mat-

* See the Note on the developement of the nervous system of the human fœtus, contained in the Appendix, also the Note at p. 270.

† The galvanic or electro-motive apparatus may be considered, "as producing, by the mutual contact of the heterogeneous bodies which compose it, a developement of electricity, which is propagated and distributed through its interior, by means of the conductors interposed between its metallic elements (plates). If we form a communication between its two poles, the discharge which follows, overturning the state of electrical equilibrium, in the series of bodies super-imposed on each other," (and forming the voltaic pile,) "causes them to be recharged, according to the conditions of this equilibrium, either at the expense of the ground, or by the decomposition of their natural electricities. The repetition, then, of such discharges, or rather their continuation, must occasion in the apparatus a continued electric current, the energy and the quantity of which depend as well on the magnitude and the nature of the metallic elements in contact with each other, as on the greater or less facility which the conducting parts of the apparatus present to the transmission of electricity."—Biot.

ter possesses a certain proportion of the electricities, may it not be allowed that, under circumstances similar to those with which experiment and observation make us acquainted, a continuous current of the different electricities is produced, the rapidity and sensible effects of which vary according to the accidental disposition and situation of the different material bodies, and their natural states of electricity. This opinion is calculated to account for many of the changes which are continually taking place on the face of our globe; and although many may not feel inclined to consider these fluids as the *chief* agents, no one can deny them a share, in producing the effects which are so frequently observed upon its surface.

The laws of electricity, whether they have been observed in connexion with its free and uncombined state, or in its form of continuous circulation, as displayed in the various galvanic processes, have been lately very closely marked and reduced even to precise calculation. From among these we may adopt the following general law, which has been clearly established by M. Biot, namely, that "*each of the two electrical principles is a fluid, whose particles, perfectly movable, mutually repel each other, and attract those of the other principle, with forces reciprocal as the square of the distance. Also, at equal distances the attractive power is equal to the repulsive.*"

This therefore being an established law which characterises the actions of these fluids, is it not reasonable to explain the material phenomena of the universe by its assistance, especially when such an explanation may be conducted in accordance with the known laws of matter, and supported by the conviction that the atoms of every material substance possess certain electrical states?

Another very important law, which regards the electric fluids chiefly with respect to the atoms of matter with which they are associated, must not be overlooked, viz. "that a mutual attraction exists between the electric fluid and all material substances, when they are in their natural state of electricity." But this is a mere extension of the former law as regards the connexion of these fluids with the atoms of matter, and is entirely the result of the electrical influence with which these atoms are endowed, as we can have no idea of matter devoid of its natural electricity.

Proceeding, therefore, upon the established laws of electricity, and upon these which, it is presumed, the particles of matter obey, it may be concluded, that the cohesion which exists between the atoms of unorganised substances results from the attraction existing between the opposite electricities. Whether we conceive the particles of matter to exist innately, endowed with certain electrical states, or surrounded with one or other of these fluids, according to their reciprocal affinity, still the attraction between the atoms of matter must be equally the result of opposite states of this universally diffused agent.

But it may be contended, that as the particles of matter mutually repel each other, they therefore are either altogether devoid of any kind of electrical influence, or are endowed with the property of mutual repulsion, which they exert notwithstanding the electrical agency. But this objection is by no means valid; for it may be shewn that, even granting them to possess the property of mutual repulsion, the supposition is favourable to the theory, and serves, moreover, to account for the varied phenomena to which the different particles of matter and the electrical fluids give rise.

As, however, we have just supposed that the attraction of matter results from the atoms being endowed with the opposite state of electricity, it is as reasonable to suppose that an opposite condition to attraction must take place when homogeneous particles, or those possessing the same kind of electrical energy, are brought within the sphere of action.

From this consideration we are led to the conclusion, that attraction and repulsion between the particles of matter arise as a necessary consequence of the electrical states of these particles. The various anomalies or peculiar conditions of material substances can be easily supposed to result from certain degrees of electrical saturation, or neutralisation, to which these substances are subjected.

From the consideration of corpuscular attraction and repulsion, the transition to chemical affinity becomes evident.

It may be shewn by direct experiment, that repulsion can be produced between two bodies, by giving one of them an electrical state different from that which it naturally possesses, that is, by bringing it artificially into a condition similar to the other; so chemical attraction between two bodies may be increased by exalting the energy of the electrical states which they naturally possess.

As chemical affinities are the result of *attraction* or *repulsion* between the particles of matter, owing to their electrical conditions, so these affinities will be simple or compound, according to the electric states of the *different* materials which are brought into mutual action, and according to the various energies of these states.

Having endeavoured to establish the proposition of different material atoms possessing different electrical states, both as regards the negative or positive modes of existence of this agent, and as respects the energy of each mode; and having considered such relations sufficient to account for the phenomena of repulsion and gravitation,—it becomes unnecessary to point the application of the doctrine to the various chemical changes which take place. However, that such changes actually do occur, after the manner which *à priori* reasoning would lead us to expect, is a general inference which presents very few exceptions. But our knowledge respecting the abstract state of those substances which present the presumed exceptions, is as yet so very imperfect, that no conclusive argument can be adduced that their chemical combination is *not* the result of the electrical states of their atoms, or of these fluids during their continuous circulation through them *

The excitement of electricity by means of

* The celebrated botanist Mr. Brown has lately ascertained that the molecules of both organised and inorganised matter are in a constant state of motion. May not this motion be, in the former class of bodies, the consequence of the electrical states of these particles, for which states we have contended above,—or, in other words, a sensible phenomenon of their elec-

friction, by compression, by the fusion of inflammable bodies, by evaporation, by the disengagement of gas, by the disruption of a solid body, by the contact of dissimilar substances, and lastly by chemical decomposition—all combine in establishing the intimate connexion for which we contend.

Whenever bodies, brought by artificial means into high states of opposite electricity, are allowed to restore the electricity, heat and light are the consequences. (Davy.)

These effects take place in the same manner if performed in a vacuum. The light thus produced appears, from the experiments which have been related, to be of the same nature with the solar beam, and to be divisible into the prismatic colours. The light exhibited by phosphorescent bodies, and by matter under its various conditions, gives similar results. Therefore, from taking a survey of the electrical phenomena, of those displayed by chemical combinations, and of other manifestations of nature, we are inclined to adopt the belief that light and caloric (as they exist in the solar rays, and as they are otherwise produced) are the result of the combination and neutralisation of the opposite electricities, whether taking place in a direct manner and in their free state of existence, or through the medium of the particles of matter which they endow; light being more or less perfect according as the neutralisation is more or less complete, and the caloric resulting from the intensity of their action.

Before leaving the consideration of the action of the electric fluids upon each other and upon the molecules of matter, it is necessary to remark respecting a property which the molecules of matter appear to possess under certain circumstances, of arranging themselves in definite directions;—this has generally been called the polarisation of matter—a phenomenon observed in the crystallisation of numerous substances, and in different chemical actions. The polarisation of the atoms of matter seems to result from the electrical states which they acquire from the electricities circulating around them, and to arise from a property with which the electricities are themselves endowed, or from their mutual action independently of their connexion with the molecules of matter. According to this view of the subject, we should be led to expect, that the electricities, as they exist in the solar beam, unconnected with matter, would give rise to the phenomenon of polarisation, in a similar manner as when their action is exerted through the medium of the atoms of matter: this conclusion is supported by the experiments of Dr. Brewster, Biot, and others, on the polarisation of light.

The intimate connexion which exists between the electrical agencies and the magnetical attractions, is a subject which has lately interested scientific inquirers throughout Europe. It would almost seem, from their observations, that manifestations of the magnetic power result from the electrised state of the atoms of the magnet, and their consequent polarisation; and from the continuous circulation of the electric fluids either through its substance or upon its surface.*

Since the discovery of Galvani, several physiologists have attempted to explain the phenomena of the animal world by imputing the functions of the nervous system to the electromotive energy, generated or developed by the cerebro-spinal masses. Amongst those who have espoused this opinion, we may mention Sprengel, Reil, Prochaska, Wilson Philip, Lenhossek, &c. There can be no doubt that the electricities circulate through animal bodies in different conditions, and give rise to subordinate offices in the animal economy, under the superior dominion of a vital influence; and, moreover, that they (or one of them at least) are a stimulus to this influence. The experiments of the physiologists just named, especially those of Dr. Philip, shew this, but nothing more than this. They refer to the electrical apparatus which certain fishes possess, and the power they have of giving electrical shocks, in farther proof of the justness of their inference: but it may be asked, if the nervous influence be the same as electricity, why should these animals possess an apparatus distinct from the nervous system, and under its control, for the production of the electrical phenomena? The existence of this apparatus confirms the proposition we have just now stated; and its office is evidently that of accumulating within itself, in consequence of the vital function with which it is endowed, the electricities circulating in the body, so that they may be discharged according to the wants of the animal: but the electricities which the animal thus accumulates and discharges, cannot be said, from the evidence which we as yet possess on the subject, to be identical with its nervous influence, nor with the vitality of its system, more than oxygen, nitrogen, hydrogen, or any other fluid constantly present in, circulating through, and combining with the constituents of the body, may be considered to be the source of its numerous manifestations. The one fluid may accumulate in the system as well as the other, by means of the vital operations of the organ in which the accumulation takes place, and it may be again discharged in consequence either of an operation determined by the nervous influence, or of some other process, and, in fact, we find such a phenomenon actually taking place; but are we to infer on that account, that either the one or the other of these fluids constitutes the vitality of the system, or even that they are the source of vitality, when it can only be shewn to be a single function from amongst the many which the animal exhibits? We find that electro-motive conditions? The motion presented by organised bodies must doubtless be ascribed to their vitality, and its concomitant changes. Motion in dead organised bodies is to be referred to the chemical changes which took place, when these changes are no longer restrained from supervening by the controlling influence of life,—which changes, as argued for above, are merely the results of electro-motive agencies.

* In the annual oration delivered to the Medical Society of London in March 1822, we endeavoured to shew that the phenomena of attraction or gravitation, chemical affinity, combustion, crystallisation, magnetism, light and heat, (both as they exist in the solar rays, and as they are otherwise produced), in short, that all the phenomena of the inorganised world and of the solar systems, may be explained by means of the agency of two universally diffused electricities.

tricity is accumulated in, and discharged from, the electrical apparatus of some fishes; and we also perceive that oxygen and nitrogen are, in like manner, accumulated in, and discharged from, the swimming bladders of other fishes; but these circumstances do not warrant us to infer that electricity is the nervous influence of the former, any more than that oxygen is the nervous influence of the latter; or that the vitality of the one is electricity, of the other it is oxygen.

But, although the agency of the electricities has been extended farther, as respects the animal kingdom, by some physiologists, than well-ascertained facts can warrant, it must be allowed, from the evidence which has been adduced, that they give rise to very important phenomena when they are brought to operate on some of the animal textures. It is these effects, or rather the stimulus which electricity imparts to the sensible and contractile parts of the body, that constitute the chief physiological relations of electricity, and give a degree of plausibility to the doctrines of those who consider that all the animal functions are discharged by the electricities in their electro-motive condition. These circumstances require that we should notice at farther length the effects of this agent on the animal system.*

"According to Ritter, the electricity of the positive pole augments, while the negative diminishes, the actions of life. Tumefaction of parts is produced by the former, depression by the latter. The pulse of the hand, he says, held a few minutes in contact with the positive pole, is strengthened; that of the one in contact with the negative is enfeebled: the former is accompanied with a sense of heat, the latter with a feeling of coldness. Objects appear to a positively electrified eye, larger, brighter, and red; while to one negatively electrified they seem smaller, less distinct, and bluish,—colours indicating opposite extremes of the prismatic spectrum."

An electrical practitioner referred to by Dr. Ure, from whom the above paragraph is quoted, considers that his experience in the application of this agent in disease warrants him in referring its operation to three distinct heads: "first, the form of radii, when projected from a point positively electrified; secondly, that of a star, or the negative fire concentrated on a brass ball; thirdly, the Leyden explosion."

The first acts, he considers, as a sedative; the second as a stimulant; and the last has a deobstruent operation. Dr. Ure has found that the negative pole of a voltaic battery gives more poignant sensations than the positive.

The experiments of Dr. Philip with voltaic electricity have led him to infer that the nervous influence is nothing else than this agent. This proposition has already been noticed, and it will be again referred to; we shall only observe at this place, that his experiments appear to shew the extent to which the electro-motive agency, transmitted through their voluntary nerves, may prove a stimulus to particular organs, and enable them to perform their functions when these functions have been impeded by the removal of a natural and requisite stimulus. We have at another place endeavoured to shew that the functions which Dr. Philip has imputed to the cerebro-spinal nerves are actually derived from another source; that the operations of these nerves (with the exception of the nerves of sense) are chiefly confined to the transmission of the cerebro-spinal influence, which is the natural stimulus to the vital endowment that the organs receive from a different system—the ganglial; but that this stimulus cannot be considered to be galvanism, merely because galvanism is a stimulus, and acts in a manner which we have every reason to suppose other stimuli would act, if they were capable of being transmitted through, and be present in, every part of the body on which they are disposed to operate. It is the particular constitution of this agent, its properties, and its relations with the solids and fluids of the body, that give rise to its active operation, and to phenomena liable to be confounded with those of the nervous system, or even with those of life itself.

What we have just now adduced has a stricter reference to the opinions of those who consider that the nervous influence and galvanism are the same; we shall now refer more particularly to the notion of the identity of this agent and life itself; and here we cannot do better than quote the very acute, conclusive, and unanswerable observations of Dr. Pring† on this subject. "We observe that electricity is related with life, and acts upon it; this is no proof of identity. We observe also that electricity will substitute in some instances the properties derived from a nervous centre; in this respect there is an identical property common to it and life, which is also possessed by many other substances. We observe also, that the formation of heat, and the faculty of generating electricity, belong to animals, and are dependent upon their life. The faculty of generating electricity in animals does not prove that electricity is even a constituent part of their life; it proves that it is a phenomenon of their life; but that it is a part of it, is no more to be concluded on this account, than that urine or mucus, &c. is a part of life, because these are also products of it.

"We have made out, then, only one point of resemblance between life and electricity, which

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* Amongst the living tissues, the nervous is the best conductor of electricity; therefore when an electrical current is established through the body, it is transmitted by this texture. If the electrical current consists only of one of the electricities, the molecules composing the nervous texture tend to propel each other, or to disunite; and if the electrical action is very intense, they are actually decomposed, and confounded with the fatty matter which isolates the nervous fibres; all the functions of the nerves are instantly destroyed, the irritability of the muscles dissipated, and life is immediately terminated. These effects are frequently witnessed from lightning. They are not confined, however, to the nervous and muscular systems, all the soft parts are more or less affected; the blood does not coagulate, owing to the dissipation of the vital influence giving rise to the phenomenon of coagulation (*see* p. 50); and all tissues fall quickly into a state of putrefaction.

† *Principles of Pathology.* We recommend the physiologist to study closely the physiological and pathological writings of this most acute and philosophical writer.

is, that electricity will in some cases substitute a property otherwise derived from a nervous centre; which property, applied to the stomach, will aid digestion, in which respect it has not yet been found that more common stimuli resemble it: applied to the voluntary muscles, it will produce their contraction; and in this respect the property is a common one to many other substances, which no one ever thought of identifying with life. But even the properties which are said to depend upon a nervous centre are not all of them substituted by electricity, which will stimulate muscular contraction, like many other substances, but, like those substances also, it is incapable of conferring sensibility; or if electrical influence ever excites sensation in paralytic limbs, it is only because their sensibility is not totally extinct, and will therefore admit of sensation under the application of this, or of any other stimulus of a powerful kind.

"We have seen that electricity can do a very little which is also done by life; there is then analogy in one property, but to be the same identity, there must be analogy in all; or to approach to such identity, there must be at least a general analogy. The living principle maintains itself by assimilation from exposure to its elements; electricity is not capable of maintaining itself from its elements, but must be produced from them. Muscular power in the animal system is related with mind, and directed by volition; we have no evidence that mind, or volition independently of the properties which distinguish the living state, can so ally itself with electricity. Animal life confers sensibility on structures; electricity can merely excite sensation in common with chemical and mechanical stimuli. The organic life produces from a common material, arranges, and renovates, in the muscular system, the particles which compose muscle; in the tendons, those of tendon; in the membranes, those of membrane; in the bones, the constituents of these structures; and of all others, with all their circumstances, however diversified. Now if electricity were capable of doing all this, there would then be established only a general resemblance with life; analogies would afterwards be sought for, corresponding with those powers exhibited by the relation of properties of life in different seats, and more especially among the phenomena of disease. But until the pretensions of electricity to an identity with life shall be established by rather a more extensive analogy, it is superfluous to inquire how far the phenomena of electricity resemble those of dyspepsia, diarrhœa, consumption, abscess, or gout. If, perchance, electricity should be endowed with the properties engaged in these phenomena, it will be greatly indebted to its friends for bestowing upon it attributes which it has never displayed. In the mean time, it is to be wished that experimentalists will go on multiplying their facts, and that they will abstain from reasoning upon them: they will not, however, err to any great extent in this way, if they will take the trouble to remember that so far as things are proved to be alike, they are alike; and where they are not proved to be alike, it is possible that they may be different.

"The identity of life and electricity or galvanism has been inferred, as appears from the preceding account, from very slender premises; but the arguments just considered are among the best that have been proposed in favour of the sameness of the two principles, or substances, if they are substances."

OF OSSIFICATION.

(Note L L. See pp. 290, 291.)

The bones are at first of a mucous or gelatinous consistence in the embryo. They next become cartilaginous, and some of them fibro-cartilaginous; they are lastly perfectly ossified. At the early period of the embryal state the bones gradually increase, without any apparent division into separate parts. The cartilaginous bones, or the temporary cartilages, do not appear before two months have elapsed from the period of conception, and then this process towards ossification only commences in those bones, or in the parts of bones, which are ossified at a later period. It appears doubtful whether or not those bones which ossify the first, or those parts of bones in which the process takes place at an early period, pass through an intermediate or cartilaginous state. It seems most probable, from the observations of MM. Béclard and Serres, that in them the ossific deposit is made in the first or mucous state of their existence; whilst, in those bones which are perfected at a remoter period, the cartilaginous or intermediate state which they assume is rather a provisional function than a state of ossification —a temporary condition of structure, for the purpose of performing the offices of bone, and not a requisite antecedent to the ossific process.

Ossification commences successively in the different bones, from about a month after impregnation, in those which are the first formed, until ten or twelve years after birth, in those which ossify at a later period; and in certain subordinate parts of bones, the ossific process does not commence until the fifteenth or eighteenth year. The clavicle and maxillary bones are amongst the first developed; the sternum, the bones of the pelvis, and those of the extremities, are the latest. It may be considered as a general proposition, that those bones which are nearest the nervous and sanguineous centres are the first to be formed, as if their more immediate developement were required to protect these important systems: hence we perceive that the vertebræ and ribs ossify at an early period.

At the end of the first month ossification commences in the clavicle, and successively in the inferior maxilla, in the femur, tibia, humerus, superior maxilla, and bones of the forearm, where it begins about the thirty-fifth day. About the fortieth day this process commences in the fibula, scapulum, the palatine bones; and during the following days, in the occipital and frontal bones, in the arches of the first vertebræ, and in their sides, in the sphenoid, the zygomatic apophysis, the phalanges of the fingers, the bodies of the vertebræ, the nasal and zygomatic bones, the ilium, the metacarpal bones, the condyles of the occipital bones, in the squamous portion of the temporal bone, the parietal, and in the vomer: in all these, ossification begins about the middle of the seventh week. In the course of the same week it appears also in the orbitar process of the sphenoid; and, about the end of the week, in the metatarsal bones and phalanges of the fingers and toes.

During the ten following days it begins in the first sacral vertebræ, and around the tympanum. During the subsequent weeks and months it commences in the bones of the ear, in the pubis, in the processes of many of the already-mentioned bones, in the small bones of the extremities, &c.

Ossification does not always result, as we have already noticed, from the transformation of cartilage into bone. The diaphysis of the long bones, and the centre of the large bones, which are amongst those first formed, pass immediately from a mucous to an osseous state. The other parts of this structure have an intermediate cartilaginous condition: and it is in these parts that the successive stages of ossification may be best observed.

The cartilage which, for a longer or shorter period, supplies the place of bone, becomes at first hollowed into irregular cavities, afterwards into canals lined with a vascular membrane and filled by a mucilaginous and viscid liquid; these canals become red, the cartilage now assumes an opaque appearance, and ossification commences towards its centre. The first point of ossification is always in the centre of the cartilage, and never at its surface. This point is surrounded by a reddish cartilage, and that part which is nearest it is opaque and pierced with canals still farther than the opacity reaches.

The osseous point augments progressively by means of additions on its surface, as well as by an interstitial deposit in its substance. The cartilage gradually becomes hollowed by cavities and canals, lined by a vascular sheath, diminishes as the ossification extends, and disappears altogether when the process is completed.

With respect to the state in which the osseous matter is formed, we are inclined to agree with M. Béclard in the opinion, that the earthy matter is deposited in a fluid condition, and at the same time with animal matter, in the organised tissue which secretes it. Its subsequent solidification arises either from the deposition of a larger proportion of earthy matter, or from the absorption of the vehicle which gives it the fluid condition; or from the joint operation of both these causes.

OF VOICE.

(Note M M. See p. 320.)

The cricoid cartilage, which supports the two arytenoid cartilages, is not immovable at the inferior part of the larynx. The trachea, to which it is attached by its inferior margin, yields and elongates itself in order to allow it motion. The muscles of the larynx do not contribute to the production of the voice solely by means of the action which they exercise on the sides of the glottis; several of them, and particularly the thyro-arytenoids, may be considered as forming a part of the parietes of this opening. These small muscles give rise to acute sounds, by drawing closer the two arytenoid cartilages, and when in a state of contraction they also seem susceptible of a vibratory motion, varying in degree according to the degree of contraction: by the assistance, therefore, of the muscular fibres covering its sides, the glottis is susceptible of vibrations analogous to that of the lips applied to the opening of a French horn. The production of sound is owing to the action of the muscles of the larynx on its cartilages during expiration; and whatever impedes the functions of the nerves actuating these muscles, puts a stop to the utterance of sound.

Of Ventriloquism, (p. 325.)—Various attempts have been made to explain the manner in which the ventriloquist is enabled to modify his articulations into the semblance of distinct voices. Dr. Good considers ventriloquism "to be an imitative art, founded in a close attention to the almost infinite variety of tones, articulations, and inflexions, which the glottis is capable of producing in its own region alone, when long and dexterously practised upon; and a skilful modification of these vocal sounds, thus limited to the glottis, into mimic speech, passed for the most part, and whenever necessary, through the cavity of the nostrils, instead of through the mouth." He farther supposes that "some peculiarity in the structure of the glottis, and particularly in respect to its muscles and cartilages," is requisite to carry this art to perfection. The explanation which Magendie offers on this subject appears to us to be more correct, although perhaps not sufficiently so. This physiologist asserts that ventriloquism consists in certain modifications of sounds or speech, produced by a larynx of the common formation, with a strict attention to the different effects of sound thrown at different distances, and through different modes of conveyance. We cannot agree with Dr. Good, that the ventriloquist performs articulation by means of the larynx only, although we may concede some share in the process to this organ; nor can it be granted that any "addition to the muscular organism of the glottis" is enjoyed by those who have perfectly acquired this imitative art.

OF THE GENERATIVE ORGANS, AND THEIR FUNCTIONS.

(Notes N N. See pp. 333, 335, 338—344.)

I. *Of the male organs of generation.*—The cellular structure of the corpora cavernosa penis, according to the microscopic examinations of M. Bauer, appears to be made up of an infinite number of thin membranous plates, exceedingly elastic, so connected together as to form a trellis-work, the edge of which is firmly attached to the strong elastic ligamentous substance which surrounds the whole, and also forms the *septum pectiniforme.* This substance has an admixture of muscular fibres. The cells are generally larger, or rather the trellis-work is more loose, in the middle portion of each corpus cavernosum.

Arterial ramifications are supported by this reticular structure, and they are distributed every where throughout the cavernous part of this organ. In the usual state of the penis, the blood is not poured into the cells, but returns by the veins, and it remains flaccid; but when a person is under the influence of particular impressions, the minute arterial branches, which before had their orifices closed, now have their action suddenly increased, and pour from their open mouths the blood into these cells, so as to overcome the elastic power that under ordinary circumstances keeps them collapsed.

The corpus spongiosum penis appears, from

the observations of the same physiologist, to consist of the same kind of structure as that observed in the corpora cavernosa, but on a less scale. Its structure is also more regular throughout; without, however, having any muscular fibres mixed with the trellis-work, these being confined to the outer surface of the inner membrane of the urethra. The erection of this part is supposed to take place after the same manner as that of the corpora cavernosa, namely, from a vital expansion taking place in the extremities of the arterial capillaries, and thus allowing the blood to flow from them into the cells of both structures.

We may state, moreover, that the arteries of the penis are surrounded by a larger proportion of nerves than in most of the other tissues of the body. The veins form very numerous anastomoses. It is the division, on dissection, of these numerous veins, and of their numerous roots, anastomoses, and plexuses, which, in the opinion of M. Béclard, gives the appearance of cells, the existence of which he denies. Erection of this texture is the result of the influence of the nerves upon the arteries and veins belonging to it. By this influence the action of the arteries is increased, whilst the diameter of the veins returning the blood is diminished by the tonic contractility which these nerves exert on the coats of the veins.

P. 333.—The vesiculæ seminales may, under particular circumstances, more likely to occur in the human species than in the lower animals, be employed as reservoirs; although their ordinary use may be to secrete a fluid which, mixing with the semen *in coitu*, may render the act more perfect, and more likely, therefore, to produce fœcundation.

P. 336 —MM. Prevost and Dumas have both examined the spermatic animalculæ. They seem to vary in form in different animals, and to be the product of a real secretion. These physiologists conclude, — "1st, that spermatic animalculæ have nothing in common with infusory ones, except in their microscopic size; 2d, that they are produced in the testes alone, but do not appear in these organs till the age of puberty; and 3d, that they seem to be the active principle or agent of the semen."

II. *Of the female organs of generation.* P. 335. — The uterus, the ovaria, and the Fallopian tubes, receive their nerves from the abdominal portion of the trisplanchnic nerves, branches of which unite variously with each other, and form six plexuses. The *first*, which M. Tiedemann calls *spermatic*, or the plexus common to the ovaria and tubes, is situated on the anterior surface of the abdominal aorta, and on the origin of the internal spermatic artery. It is formed of a number of branches which come from the renal ganglia. Its filaments descend, surrounding the arteries of the ovaria, between the membranes which form the broad ligaments of the uterus, and arrive at the ovaria and tubes, in which they are ramified; a few filaments reach the fundus of the uterus.

The *second* plexus, which is the largest, M. Tiedemann calls the *superior lumbar plexus*, or *common uterine*. It is formed of branches which proceed from the superior lumbar and renal ganglions; and is placed on the body of the fifth lumbar vertebra, and on the promontory of the sacrum, between the iliac arteries. On its entrance into the pelvic basin, it divides itself into two considerable plexuses, which M. T. calls the *hypogastric* or *lateral uterine plexuses*. These are placed on the trunks of the iliac arteries, and anastomose with the first and second sacral ganglions. A great many filaments proceed from these plexuses, forming a reticulum around the arteries of the uterus, with the ramifications of which they penetrate into the texture of the organ, chiefly its posterior and lateral aspects.

Several branches proceed from the superior lateral or *hypogastric plexus* to the vagina, at the point of its union with the neck of the uterus, and there unite with the anterior branches of the third and fourth sacral nerves, and form a large plexus, which M. Tiedemann calls the *inferior lateral hypogastric*, and which interweaves with and embraces small ganglia. This gangliform plexus gives origin to a great many branches, chiefly to the vagina, to the uterus, and also to the bladder and rectum. These nerves, as well as those belonging to the other plexuses, always closely embrace the arteries in the form of a net-work.

It appears, therefore, that the womb and its appendages are surrounded by important nervous plexuses. These nerves are soft, small, reddish-gray, and in every respect similar to the other portions of the great sympathetic nerves. Of their appearance and character we have had several opportunities of satisfying ourselves, when making researches respecting this grand organic system; and we can bear testimony to the correctness of the observations of M. Tiedemann.

M. Tiedemann states, that the number and size of the uterine nerves vary according to the age of the female; that they are small and apparently few in girls — large and numerous in adults—and very small in old women. He has observed another fact, confirmatory of their functions, which indeed was previously noticed by Dr. W. Hunter and Professor Chaussier, that these nerves become larger and more numerous during gestation,—a fact which we have verified on several occasions.

III. *Of impregnation.* P. 339 — Several opinions have been entertained respecting the impregnating process. Some physiologists suppose that the actual contact of the ovum and semen are requisite; others that the *aura seminalis* is all that is requisite. Of the former class of physiologists, some suppose that the semen is absorbed into the uterus, where the ovum, having descended through the Fallopian tubes, meets it; others consider that the semen is conveyed by a peristaltic-like action of the vagina, uterus, and tubes, to the ovarium, — and they adduce in support of their opinion the occurrence of extra-uterine fœtation; a third party belonging to this class conceives that the semen is conveyed to the ovum itself, in its situation in the ovarium, by means of absorption, through a set of vessels allotted to this specific purpose. Dr. Dewees, of Philadelphia, has argued strenuously for this last doctrine; it has also been adopted by other physiologists; and it seems to have received support from the labours of Dr. Gartner, of Copenhagen, who has discovered, in some animals, a duct leading from the ovary to the vagina. The occurrence of ovarian fœtation wherein the fœtus is lodged within the enveloping membrane of the ovarium, can be most satisfactorily explained by means of this doctrine. Two cases of this description have lately been detailed by Dr. Granville and Mr. Pain-

ter. It must, however, be allowed, that the latter class of physiologists, or those who contend for the impregnating influence of the aura seminalis, have it in their power to adduce strong arguments in behalf of their opinion. It has even been asserted, very recently, by some continental physiologists, that the impregnating power of the aura seminalis may be proved by experiment performed on rabbits, in the following manner: — Let the semen be received in a cup, over which is to be immediately placed an inverted funnel; and let the apex of this funnel be introduced into the vagina. If this experiment be performed immediately after the seminal emission, they say that impregnation will be the result.

It has been argued, that the venereal desire is present in neither sex before the developement of the testes and ovaria. This, however, is not the case. The venereal appetite makes its appearance in both girls and boys long before the generative organs are developed. It has been frequently observed in them both, in temperate climates, as early as the sixth or seventh year. It has also been supposed, that the venereal appetite disappears soon after the menses have ceased to flow; this also is not the case.

With respect to the assertion, that the venereal orgasm on the part of the female is necessary to impregnation, we may observe, that although it may be requisite in some females, it is by no means so in others; for many women conceive who are indifferent during the venereal congress; there are others who conceive, notwithstanding their successful endeavours to suppress their orgasm; and some are impregnated, when, owing to disease, as procidentia uteri, &c. they cannot be supposed to enjoy much pleasure from the act.*

Dr. Blundell found, in his experiments, that when only one of the uteri of a rabbit was divided, or rendered impervious at its neck, or when the passage to both was obstructed by tying the vagina, and afterwards freely admitted to the male, that the obstructed uterus, or uteri, did not become impregnated; but he found, in those whose vagina was tied, that, notwithstanding, the ovaries, Fallopian tubes, and womb, were excited by coition; and in those who admitted the male frequently, the abdomen acquired a large size, and in some cases exceeded the bulk of mature gestation. These enlargements arose from an accumulation of a humour in the womb, which, at a temperature below boiling, formed albuminous concretions. In its appearance it was various, but generally fluid, pale, and turbid. In those who had only one uterus obstructed, the sound one became filled with fœtuses, and the barren one with the humour described. The formation of the lutea, the developement of the womb, and the repeated accumulations of fluid, in consequence of coition, in these experiments, seem to indicate the descent of the rudimental material.

Thus, although the passage to the uterus was completely interrupted, the tubes were excited by the venereal orgasm, they really conveyed the rudiments to the womb, and these rudiments engendered the watery accumulations there, in the abortive attempts at generation. This appears to confirm the supposition, and indeed to establish it, that even in viviparous animals, generation may be carried to a certain extent, although the access of the semen to the rudiments is interrupted: under these circumstances, the young animal cannot be formed, it is true, but corpora lutea may be generated, the womb may be developed, and the rudiments may even be transferred to the uterine cavity by the play of the Fallopian tubes. This opinion receives countenance from the generation of oviparous animals, in most of whom the rudiments may be discharged, independently of preceding impregnation.†

Dr. Blundell supposes that the vagina and womb perform a peristaltic motion, from the stimulus of the semen, both in the human subject and lower animals; and that this motion conveys the semen to the rudiments.

From these experiments it would appear, that the presence of corpora lutea cannot be relied upon as a proof that impregnation had taken place. There is evidence that they may be produced even independently of the sexual intercourse, from the mere excitement of desire in a high degree. Dr. Blundell has in his possession a preparation of the ovaria of a young woman who died of chorea, under seventeen years of age, in which the hymen was unbroken, and nearly closed the entrance of the vagina. In these ovaries the corpora lutea are no fewer than four — two rather obscure, the other two perfectly distinct.

As Dr. Blundell's experiments go to prove that impregnation cannot take place without the semen coming in contact with the rudiments, he therefore supposes, that when the ovary lodges either in the tubes, the peritoneal cavity, or in the ovary itself, and there impregnated, that the semen must be conveyed to those situations. Or, that the rudiments in their descent meet the semen in its ascent, and that the transfer of the

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* Sir Everard Home (Phil. Trans. 1818,) states that corpora lutea are never met with before puberty. They are formed in the loose structure of the ovarium previous to, and independent of, sexual intercourse; and when they have fulfilled their office of forming ova, they are afterwards removed, by absorption, whether the ova be impregnated or not. It seems that the ovum too, with its amnion and chorion, is formed in the virgin *after* puberty. This was found to be the case in a woman of twenty years of age, who had a perfect hymen. "The Fallopian tube of that side was fuller than the opposite. The fimbriæ were spread out, and unusually vascular." We know that animals part with their eggs whether there be sexual intercourse or not; and this is done with such force during coition, that the cavity of the corpus luteum is absolutely inverted, so that the ovum is exposed completely to the emission of the male. Extravasation of blood follows the rupture of the ovum frequently to so great a degree, that blood occasionally passes out through the vagina. In nine months after impregnation the corpus luteum is nearly absorbed, but a new one is usually found in a state of forwardness in the other ovarium. All preparations of corpora lutea, which are made from women who have died in child-bed, belong, in Sir E.'s opinion, to ova which were to succeed, not to the ovum of the child which had been born.

† Med. Chirug. Trans. vol. x.

semen beyond the womb may be the cause of extra-uterine pregnancy.

IV. *Of Superfœtation.*—M. de Bouillon* has adduced an instance of superfœtation in a negress. At the end of her pregnancy she was delivered of two male children, full-grown, and of the same proportions, but the one a negro and the other a mulatto. The mother, after a long resistance, confessed that she had connexion the same evening with a white and a negro. Similar instances have lately been detailed in the American journals, of which we shall only instance the following:—A white woman, near Philadelphia, is said by Dr. Dewees to have been delivered of twins, one of whom was perfectly white, the other black. The latter of these had all the characteristics of the African, whilst the former was delicate, fair-skinned, light-haired, and blue-eyed. Similar cases have been detailed by Dr. Elliotson, and Drs. Norton and Stearns, of New-York.

Superfœtation, in our opinion, can only take place under circumstances similar to those which produced it in the foregoing instances:—in them, it would seem, that there had been connexion with different individuals within a short space of time. We conceive that, when the decidua is thrown out, and the ovum has formed its connexions, superfœtation is then impossible, unless in the case of a double uterus.

OF THE DEVELOPEMENT OF THE TEXTURES AND ORGANS OF THE FŒTUS.

(Note O O. See pp. 344—353.)

It was our intention to have illustrated this subject at considerable length; but we have so far exceeded our limits, that we must now be brief.

1. *Of the developement of the fœtus.*—At first the embryo appears to be only a semi-liquid vesicle, and to consist of minute globules disseminated through a more fluid medium, which presents an oval or spheroid form.† As the embryo advances, the proportion of solid matter increases, and continues to increase to the termination of the life of the individual. The first stage of its existence resembles that of the polypus; and the globules which may be observed in its otherwise homogeneous texture closely resemble those which are observed in the nervous system. At first the embryo is colourless; it afterwards presents a gradual developement of colour, and at last a coloured fluid may be discerned. From a state of organisation consisting merely of disseminated globules — fibres, membranes, and vessels, come successively into existence. The organs, as we have already said, are not formed at once; they are gradually developed. Even particular systems do not assume at once their form of organisation, but are developed by degrees, and run through the same stages of organisation as may be remarked in the animal scale. This is particularly remarkable as respects the developement of the nervous system.‡ — See the note on this subject, p. 60.)

The exterior form of the fœtus seems to be assumed before its tissues attain any considerable degree of consistence. The glandular viscera are at first formed in isolated parts. The globules of the nervous system first appear; these become united into chords and ganglia. The vessels commence in isolated vesicles, which become elongated, and connected in regular series. The intestinal tube seems to be the viscus which first presents a definite conformation. It is at first straight, and afterwards it curves forwards, and is embraced by the umbilical chord: it thus forms an angle, and descends into the abdominal cavity, which is open at its anterior aspect, and apparently continuous with the short and imperfectly developed chord. This turn of the intestinal canal, and its retention in the chord, seems to form the umbilical vesicle; and the subsequent strangulation of the intestine, by the constriction and elongation of the chord, first gives rise to an isolated appearance of this vesicle; subsequently, to its entire disappearance; and lastly, to the separation of the intestines; the vermiform appendix remaining as a type of the original conformation.

About the same time that the intestinal tube curves into the umbilical chord, the urinary bladder seems to be also prolonged into the chord, between the chorion and amnion, forming the allantois and urachus, the former of which disappears as the fœtus is developed and the chord lengthened, the urachus only remaining at the time of birth, shewing the nature and type of the original conformation, and the communication formerly existing between the allantois and bladder.

We have already said, that all the phases through which the human embryo passes until its conformation is perfected, correspond with the different stages of permanent organisation which characterise the animal scale. Since these observations were first published by us, we perceive that a similar opinion has been entertained by J. F. Meckel, and adopted by M. Béclard in his excellent work on General Anatomy. Many proofs may be adduced in support of this doctrine: so evident indeed is the analogy, that a very close parallel may be drawn between the stages of developement through which the human fœtus passes, and the degrees of animal organisation.

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* Bulletin de la Faculté et de la Société de Médicine, No. 3.

† Mr. Bauer says that he has detected the human ovum on the eighth day from coition. It consisted of two membranes: the external one open throughout its length, but with its edges turned inwards, like the shells of the genus *voluta;* the internal membrane pointed at one end, and obtuse at the other, slightly contracted in the middle, and containing a slimy fluid and two vesicles.

‡ It would appear, that, in the process of the growth of the embryo even of man, during the first days of its existence the nervous system can only be traced as it exists in the polypi; its globules seem dispersed through the embryal structure: as the ovum advances, the ganglial branches, and the ganglia themselves, make their appearance, the nerves of sensation and voluntary motion, the spinal chord, and the brain, being successively formed. See the remarks on the Developement of the Nervous System.

The human embryo is at first an imperfectly formed vesicle: such are the polypi and others of the *zoophytæ*. At a remoter period it consists of a small vermiform body, without a distinct head or limbs: such are the *echinodermata* and the *annelides*. At a still later period its limbs are equally developed, and its tail is prominent: such are the *quadrupeds*.

As respects the nervous system, the ganglial or vital nerves first appear with the ganglions: such is the nervous structure of the invertebrated animals. As the embryo advances, the ganglial nerves give rise to two thin strips of medullary matter, in the situation of the spinal canal,-these increase, coalesce, form the spinal and cervical marrow (medulla oblongata), and the tubercles of the latter, whence are produced the brain and cerebellum: we observe the same conformation in reptiles, fishes, &c.

The human fœtus is remarkable for the rapidity with which it runs through the early grades of the scale of organisation. It is this circumstance that renders the early changes which it experiences so difficult to be recognised.

II. *Of the developement of the nervous system.*—Viewing the nervous system throughout the numerous classes of animals, and tracing the process of its formation from the embryo up to the period of perfect fœtal existence in the perfect animals, especially in man, we are led to infer that this system is not originally formed from the centre towards the circumference, but that the origin of its ramifications commences in the mucous or cellular tissue, when the embryo is yet but in an apparently homogeneous state; and that as the textures become, in the process of fœtal growth, more and more developed, so the globules composing the nervous system, and chiefly those of the ganglial system of nerves, are arranged into chords of communication, chiefly in the course of the vessels, for the purpose of preserving a connexion between the organs, and reinforcing each of the textures with the influence which they generate in their perfect state of developement. As the process of fœtal growth proceeds, the nervous ramifications advance towards centres, which vary in their characters according to the species of the animal; in those which are more perfect, those centres are numerous, and almost each differs in a more or less sensible manner from the other, both as to appearance and function.

At an early period of fœtal life the ganglial ramifications and centres are first formed, and afterwards the ramifications and centres of the voluntary nerves. In the more perfect animals, even that part of the nervous system which is general throughout the animal creation, and which the lowest orders of it possess, is the first formed; and that part which is destined to perform the highest functions, and which the perfect animals only possess, is produced the last.

III. *Of the developement of the heart and lungs.*—J. F. Meckel has concluded from his observations, 1st, The heart is relatively larger, the younger the embryo. For in his observations he found, at the first period at which the heart could be distinguished, that it filled completely the thoracic cavity.

2d, The heart is more symmetrical with respect to situation and form, soon after its formation, than at a more remote period.

3d, The form of the heart undergoes various changes during the growth of the fœtus.

A. The proportion between the arterial and venous portions of the heart is not always the same. The auricles surpass the ventricles in capacity, in proportion as the embryo is younger.

B. The relative volume of the two sides of the heart is not always the same at all periods. In the adult the right side always more or less exceeds the left; but in very young embryos the two ventricles are equally capacious, but that of the right side increases rapidly. The right auricle surpasses the left in size in the fœtus, and it is only by degrees that the left becomes equal to the right.

C. The right ventricle is unquestionably smaller than the left at first.

D. The thickness of the parietes of the heart is much more considerable at first. The two halves of the heart equally present this difference, but the right ventricle always appears a little thicker than the left. This is, however, less, the younger the fœtus.

E. The two ventricles communicate with each other at an early period, and, according to all appearances, continue to do so until the end of the second month, by means of an opening in their interior aspects, situated at their base, and immediately beneath the origin of the great vessels.

F. The interior disposition of the auricles with respect to their communication, either with one another, or with the venous trunks, undergoes considerable changes. These turn chiefly on the form and size of the oval hole, the situation of the orifice of the vena cava inferior, the situation, the form, the extent, and relations of the valve of Eustachius, and that of the foramen ovale. Here M. Meckel's researches confirm those of Sebatier and Wolff.

4th, The disposition of the aorta and of the pulmonary artery offers several considerable changes in succession, of which the following are the chief:—

A. At first there exists only an aorta. A pulmonary artery is formed at a remoter period, It is not until after the seventh week that the pulmonary artery begins to appear, and then it is only a second aortic trunk, as yet without branches—a right aorta, proceeding in the direction of the lungs, which are very distant, and extremely small.

The disposition of the large arteries at this period (seventh week) nearly resembles what it continues to be, in reptiles, during the whole life of the animal.

B. It is in the course of the eighth week only, that the branches of the pulmonary artery can be discovered. They are then much smaller, when compared to the trunk of the artery and to the arterial canal, the younger the embryo. At five months they become equal to this canal, and afterwards they surpass it, frequently so far, that when the fœtus has completed the ninth month, each principal branch of the pulmonary artery is as large as it is, or even larger.

The venous canal presents similar appearances. It is during the first periods of the existence of the fœtus that it offers, proportionally, the greatest amplitude. All the observations which M. Meckel has made, confirm the law, which is the more important, as it throws considerable light on the functions of this canal. Indeed it is probable that this conformation is only the remains of a disposition which may be seen at the epoch when the liver has not come into existence, when the vena porta and the

vena cava inferior form but one trunk, as the pulmonary artery forms, at the early stage of its existence, only one with the aorta. This conjecture respecting the origin of the venous canal is confirmed by the organisation of the acephalous class of animals, in which the veins of the intestinal canal, and consequently the vena porta, also open immediately into the vena cava inferior.

5th, The lungs are not formed until a more advanced period.

In man, manifest traces of them cannot be seen before the sixth or seventh week. Then they advance beneath the heart, at the two sides of the inferior extremity of the pectoral portion of the aorta. At the period of their appearance, and even for some time afterwards, they are so small, in proportion to the heart and the other organs, that it requires the greatest attention in following their progressive developement, to be convinced that they are in reality the rudiments of the respiratory organ.

At first the lungs closely approach one another: they are flat and of a whitish colour. Their surface is perfectly united; but on their external border may be observed, at an early period, indentations, which are the traces of the approaching separation of the lobes, notwithstanding that these lobes are not yet in existence. At a farther advanced period the lobes appear to be composed of lobules. These latter are at first larger and much less numerous, in proportion, than at subsequent periods, but they separate by degrees into others much smaller. At the period when they are first observed, they are as much more apparent, and as much less intimately united, by cellular tissue, as the embryo itself is younger.

6th, As the lungs become developed, in the reptiles and leeches, in the form of an empty sac, it is natural to suppose that their production in animals of a higher order takes place according to the same manner and law. M. Meckel endeavoured to ascertain whether or no this was actually the case. But, under whatever aspect he viewed the lungs at the early stages of their formation, even with the assistance of the microscope, he always found the slices which were removed from them completely solid: if they are really so during this epoch, it would seem as if they had some analogy of structure with the branchiæ of fishes.

7th, The branches of the pulmonary artery, which proceed from the right or pulmonary aorta, are at first certainly wanting. It must therefore be admitted, that at this epoch their places are supplied by the bronchial arteries, especially by the inferior, since the lungs are at first placed low in the inferior part of the chest. Moreover, this depending situation of the respiratory organ, at the commencement of its developement, is remarkable under two points of view:—

A. Since, amongst reptiles, and many of the mammiferi, the lungs are placed much lower than in man, and below the heart, in every respect like the fishes, the swimming bladder is placed below this organ.

B. Because it seems that the lungs and the thymus gland correspond in their functions, the developement of the one being in direct proportion to the decrease of the other.

J. F. Meckel concludes from the researches of which we have given an abridged outline, that the general results confirm it to be a grand law of the animal economy, that the embryo, from the instant of its formation until that of its maturity, rises successively through many inferior grades of organisation, and that the principal monstrosities of the heart and large blood-vessels depend upon these organs being arrested at some one grade or degree of organisation, instead of following the progress of the others towards perfection.

IV. *Of the circulation of the placenta and nutrition of the fœtus.*—There are abundant facts to prove that the circulation of the fœtus is independent of that of the mother; that the blood of the former flows from the umbilical arteries into the vein of the same name, and not from the uterine arteries into that vein; that the fœtal blood is fabricated by the fœtus itself from the juices furnished by the mother to the placenta, and absorbed by the radicles of the umbilical vein; and, consequently, that the fœtus does not receive one drop ready formed from this organ.*

In proof of the correctness of this opinion, we may refer to the experiments performed by M. Gaspard,† in order to ascertain this point; to the formation of the blood in the impregnated egg on the second or third day after incubation; and to the fact that, in the numerous tribe of oviparous animals, the fœtuses are insulated from the mother, and are the real manufacturers of their own blood.

Admitting, therefore, that the fœtus is the fabricator of its own blood, from the nutritive juices derived from the placenta, by what organs, it may be asked, is the sanguifying process performed? The great size of the liver during fœtal existence, the early formation of this viscus, and the large quantity of blood which is conveyed to it by the umbilical vein, would suggest it as the chief organ of sanguification. We have already referred‡ a sanguifying function to the liver as well as to the lungs, during extra-uterine life, and we believe that this function, which cannot be performed by the lungs during fœtal existence, is chiefly accomplished by the liver. Some authors conceive, particularly M. Geoffroy St. Hilaire and Dr. R. Lee, that the blood circulating in the liver of the fœtus supplies an abundant bilious secretion, of a mild or albuminous character, which, when poured into the alimentary canal, and mixed with the mucous secretion of the bowels, is there digested and converted into chyle, and carried into the fœtal circulation for its nourishment. This opinion seems very probable. The sanguifying process of the liver appears to us intimately connected with a secreting function, the former in a great measure depending upon the latter; or, in other words, the secretions performed by this organ being the elimination of matters from the blood, the discharge of which

* D. F. Lavagna concludes that the menstrual blood differs from common blood only in containing no fibrin; also, that the blood in the umbilical arteries of the funis contains scarcely any fibrin, whilst that in the umbilical vein forms a tenacious jelly: hence he infers that the blood acquires fibrin in the circulation in the placenta, which it parts with in its passage through the fœtus.—*Annali di Medicina di Milano*, No. 17.

† *Journ. de Physiol. Experiment.* No. 3.

‡ See Appendix, Note M. p. 22.

is necessary to the perfect state of sanguification. It should, however, be recollected that a very large part of the bile secreted during extra-uterine life is actually recrementitious; and wherefore may it not be altogether so during the comparatively short period of fœtal existence?

Other peculiarities of the fœtus are adduced in the different sections of this Note; but on these, and various other subjects,—many of which we could not even enter upon,—our limits have obliged us to be extremely brief.

V. *Respiration of the fœtus.*—The thymus gland appears to assist the placenta, the liver, and the secretion of fat, in the respiration of the fœtus, or rather in purifying the blood of the fœtus. It seems to form a nidus for the reception of those elements of the blood, carbon and hydrogen, which are secreted in a state approaching to fat, and which, if too abundant in this fluid, would endanger the existence of the fœtus. These materials on the commencement of active respiration are again absorbed, to be discharged from the economy by the lungs, liver, or intestinal canal. The thymus gland in the human fœtus, in the ninth month, generally weighs from 160 to 180 grains; at twenty-eight years of age, only 90 grains.

In the calf it weighs sixteen ounces, in the cow nine ounces.

" Etenim *placenta, hepar, adipis aucta secretio* respirationi, sed aliud alio modo, inserviunt. Quæ naturæ institutio, ut in fœtu organon alterum alterius vices obtinere possit, pulcherrima et præstantissima; quo fit, ut fœtus vita nondum autonomica, à noxiis quibuscunque momentis, quæ vim in ipsum habere possunt, tueatur conserveturque, donec ex asylo matris in lucem aëremque editus vim innatam exerceat.

"Vena umbilicalis illo principio (oxygenio) gravida partim in hepar, partim in venam cavam inferiorem sanguinem reducit à partibus phlogisticis liberatum. Itaque vena cava inferior, postquam sanguinis partem ex venà umbilicali et venis hepaticis excepit, præter sanguinem oxydutum, venosum quoque sanguinem ex corporis partibus reducem continet, cujus tamen pars satis magna, sanguis lienalis ac meseraicus, in hepate jam carbone relicto, mera existit. Quoniam verò vena cava inferior prima vitæ fœtalis parte magis in sinistrum quàm in dextrum cordis atrium aperitur, sanguis autem venæ cavæ superioris, nil minus quàm oxygenium ducens ex dextro cordis atrio per arteriam pulmonalem, hinc per ductum Botallicum, demum, postquam jam arteriæ superiorum partium ex aorta excreverunt, in ipsam perfunditur;—sequitur caput atque extremitates superiores sanguinem magis oxydatum, seu, si mavis, dephlogisticatum, in atrio sinistro ventriculoque congestum, accipere;—aortam verò descendentem sanguinem ex venâ cavâ superiori phlogisticum nec oxydatum in abdomen atque extremitates inferiores perducere, quo fit, ut superiores corporis partes, exceptis pulmonibus, qui sanguinem ex venâ cavâ superiori venientem venosum accipiunt, primo graviditatis tempore magis vigeant polleantque." P. 215.

"Placentâ oxygenium afferente, hepate carbonium submovente, quæ functiones in adulto in uno pulmone conjuctæ sunt."* P. 216.

M. Geoffroy St. Hilaire, proceeding on the principle that there cannot be organisation without the combination of a nutritious fluid, nor yet assimilation without oxygenation or previous respiration, endeavours to shew:—1st, That a respirable gas is present in the amniotic fluid, as shewn by the experiments of MM. Chevreuil and Lassaigne; 2, That the fœtus, by means of its pores, as by so many tracheas, in the same manner as aquatic insects, is enabled to consume the air contained in the surrounding fluid, owing to the air being thus brought in contact with the venous blood which fills the capillaries of the skin; 3d, That the contraction of the womb and of the abdominal muscles keeps up a certain degree of pressure, which is as requisite to the perfect performance of this process as to the ordinary act of respiration.†

OF THE VARIETIES OF THE HUMAN SPECIES.

(NOTES P P. See p. 376.)

Buffon, Blumenbach, Prichard, Gavoty and Touluzan, Cuvier, and others, have proposed classifications of the varieties of the human species: of these we prefer that of Cuvier. The following is an outline of it:—

1st, The fair, or Caucasian variety; 2d, the yellow, or Mongolian; 3d, the negro, or Ethiopian.

1st, CAUCASIAN. *Characters.*—The beautiful form of the head, the variable shades of complexion, and colour of the hair.

Principal Branches.—1. The Syrian, whence have proceeded the Assyrians, the Chaldeans, the Arabs, Phœnicians, Jews, the Abyssinians, Arabian colonies, and ancient Egyptians. 2. The Indian, German, or Pelasgic branch was early subdivided into the Sanscrit, the Pelasgi, the Teutonic, and Slavonian. 3. The Scythian or Tartarian branch.

2d, MONGOLIAN. *Characters.*—Prominent cheek-bones; flat visage; narrow and oblique eyes; straight and black hair; scanty beard, and olive complexion. Its civilisation has always remained stationary.

3d, The NEGRO. *Characters.*—Black complexion; woolly hair; compressed cranium, and flattish nose.

"It is very difficult to refer the *Malays*, or the *Papuas*, to any one of the three great varieties of mankind already described. It is a question, however, whether the former people can be accurately distinguished from their neighbours on either side; the Caucasian Hindoos on the one, and the Mongolian Chinese on the other.

"The *Americans* themselves have not yet been properly referred to either of the other races, nor have they characters precise and constant enough to constitute a fourth variety. Their copper-coloured complexion is not sufficient. The black lank hair and scanty beard would seem to approximate them to the Mongoles, if their well-defined features and prominent noses did not oppose such a classification: their

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* *Joannis Mueller de Respiratione Fœtûs Commentatio Physiologica, in Academiâ Borussicâ Rhenanâ præmio ornata. Lipsiæ*, 1823. P. 159.

† *Rev. Méd.* Dec. 1823.

languages are likewise as innumerable as their tribes, and no mutual analogy has yet been ascertained between them, nor any affinity with the dialects of the ancient world."*

We are inclined to infer that America was peopled by the Mongoles from Asia; and that, subsequently, it had been visited by Phœnician navigators, the greater part of whom settled in it, particularly in Mexico; and that the imperfect navigation of that era prevented many of the adventurers, if not all of them, from returning.

OF THE MORTALITY OF FEMALES AT THE CHANGE OF LIFE.

(NOTE Q,Q. See p. 383.)

From the bills of mortality of both sexes, collected in Provence, Switzerland, Paris, Berlin, Sweden, and Petersburgh, it would seem, 1st, that from 30 to 70, no other increase takes place in the mortality of females than what naturally results from the progress of age; 2d, that at all periods of the life of man, from 30 to 70, a greater mortality occurs than in women, but especially from 40 to 50.†

APPENDIX, No. II.

CHEMICAL CONSTITUTION OF THE SOLIDS AND FLUIDS OF THE HUMAN BODY.

I. SIMPLE SUBSTANCES ENTERING INTO THE CONSTITUTION OF THE DIFFERENT ANIMAL PRINCIPLES OR CONSTITUENTS OF THE HUMAN BODY.

The following simple substances are variously combined, in order to produce the *constituent parts* of the body :—

1 Azote.	8 Soda (*Sodium*).
2 Carbon.	9 Potass (*Potassium*).
3 Hydrogen.	10 Muriatic Acid.
4 Oxygen.	11 Magnesia (*Magnesium*).
5 Phosphorus.	12 Silica.
6 Lime.	13 Iron.
7 Sulphur.	14 Manganese.

Of these, magnesia and silica may be considered as foreign bodies, they being seldom found, and in exceeding small quantities. The principal elementary ingredients are the first six: animal substances may be considered as chiefly composed of them. The first four constitute almost entirely the soft parts, and the other two form the basis of the hard parts.

II. ANIMAL CONSTITUENTS OR PRINCIPLES.

I. GELATIN consists of carbon, 47·88; hydrogen, 27·20; oxygen, 27·20; azote, 17·00; or, of 15, 14, 6, 2 atoms respectively,—contained in skin, bone, tendons, &c.—*Test*, Tannin.

II. ALBUMEN.—Corrosive sublimate detects $\frac{1}{2000}$ part the weight of the water containing it. COMP.: Carbon, 52·883; oxygen, 23·872; hydrogen, 7·540; azote, 15·705, in 100 parts. Dr. Prout found it to consist of 15 atoms of carbon, 6 of oxygen, 14 hydrogen, 2 azote, according to the analysis quoted.

III. FIBRIN varies in its species in the different classes of animals. COMP.: Carbon, 53·360; oxygen, 19·685; hydrogen, 7·021; azote, 19·934. Consists of carb. 18 atoms, oxyg. 5, hydrog. 14, azote 3.

IV. COLOURING MATTER OF THE BLOOD.—Berzelius found it possessed of nearly the same properties as fibrin. It is soluble in water at a low temperature, and in all the acids except the muriatic: contains iron.‡

V. UREA OR NEPHRIN, soluble in water and in alcohol. Precipitated in pearly crystals by nitric acids and oxalic acid. Dissolved by a solution of potass or soda. Constituents according to Dr. Prout :—

Oxygen .. 39·5	2 atoms	Hydrog.	0·25	6·66
Azote ..... 32·5	1 ——	Carbon .	0·75	20·00
Carbon ... 14·7	1 ——	Oxygen	1·00	26·66
Hydrog. .. 13·3	1 ——	Azote	1·75	46·66
100			3·75	100

Gelatin is insoluble in cold water, albumen is insoluble in hot, and fibrin is insoluble in both cold and hot.

The constituents of these three bodies, and of nephrin, according to the best analysis of them hitherto made, are as follow :—

	Carbon.	Oxy.	Hydro.	Azote.
Gelatin	atoms 15	6	14	2
Albumen	—— 17	6	13	2
Fibrin	—— 18	5	14	3
Nephrin	—— 1	1	2	1

The colouring matter of the blood approaches albumen in many of its properties; but it seems entirely destitute of azote.

VI. MUCUS.—Insoluble in water, transparent when evaporated to dryness, and, like gum, soluble in the acids. Not soluble in Alcohol or ether—does not coagulate by heat—nor is pre-

* *Griffith's Trans. of the Règne Animal.*

† M. Bénoiston de Châteauneuf on the Mortality of Females from 40 to 50 years of age. Paris, 1822.

‡ Berzelius, vol. iii. Med. Chirurg. Trans.

cipitated by corrosive sublimate or by galls. Is precipitated by the acetates of lead, and by nit. argenti. Found in the epidermis, in nails, feathers, &c.*

VII. Osmazome is, probably, only an altered state of fibrin. Soluble in water and alcohol—does not gelatinise. Precipitated by nit. argenti, nit. hydrarg., and acet. and nit. of lead.

VIII. Picromel.—Found principally in bile; resembles inspissated bile in its appearance; soluble in water and in alcohol:—

5 atoms	Carbon	3·75	54·53
1 ——	Hydrogen	125	1·82
3 ——	Oxygen	3·000	43·65.†

IX. Sugar of Milk, according to Berzelius, consists of oxygen, 53·359; carbon, 39·474; hydrogen, 7·167.‡

Dr. Thomson gives the table of the atomic analysis as follows:—

4 atoms	Oxygen	4	48·4
5 ——	Carbon	3·75	45·4
4 ——	Hydrogen	0·50	6·2
		8·25	100·0

X. Oils are fixed.—*Fat—Cholesterine.*—The former is composed of oxygen, hydrogen, and carbon. The latter, according to Saussure, consists of 84·068 of carbon, 12·672 of hydrogen, and 3·914 of oxygen; and differs little from the other fixed animal oils, excepting that it contains more carbon and less oxygen than they.

XI. Acids. — The acids found constituting and ready formed in animal bodies, are the following:—

1 Phosphoric.	6 Uric.	11 Acetic.
2 Sulphuric.	§7 Rosacic.	12 Malic.
3 Muriatic.	8 Amniotic.	13 Lactic.
4 Carbonic.	9 Oxalic.	14 Silica.
5 Benzoic.	10 Formic.	

It may be remarked, that the whole of the soft parts of animals consists chiefly of albumen, fibrin, and oils; and the hard parts of phosphate of lime. The other animal principles are only in small quantities, and in particular textures. The oils seldom enter into the structure of the organs of animals; they serve rather to lubricate the different parts, and fill up interstices.

III. Individual Textures and Fluids of the Human Body (formed of two or more of the foregoing Constituents).

The Constituents of the Bones *and* Teeth *of some of the Mammalia, according to the Analyses of Berzelius and other Chemists.*

Substances analysed.	Cartilage, with the water of crystallisation of the earthy salts and gelatin.	Soda, with a little of the muriate of soda.	Carbonate of lime.	Phosphate of lime.	Fluate of calcium.	Phosphate of magnesia.
Human bones recently dried . . .	33·3	1·2	11·3	51·4	2·	1·16
Bullock's bones recently dried . .	33·3	2·45	3·85	55·45	2·9	2·05
Osseous parts of human teeth . .	28·0	1·4	5·3	61·95	2·1	1·25
Osseous parts of bullock's teeth .	31·0	2·4	1·38	57·46	5·69	2·07
The enamel of human teeth. . . .	2·0	...	8·0	85·3	3·2	1·5
The enamel of bullock's teeth . .	3·56	1·4	7·1	81·0	4·2	3·0

* Bostock, in Nicholson's Journal, vol. xi. p. 251.

† Dr. Thomson, An. Ph. vol. xiv. p. 69.

‡ Annals of Philos. vol. v. p. 266.

§ Forms the lateritious sediment in fevers, &c.

The compact and cellular substances of human bones are, according to Berzelius, of the same composition.

Substances submitted to analysis.	Cartilage.	Phosphate of magnesia.	Sulphate of lime.	Phosphate of lime.	Carbonate of lime.	Water and lime.	
Recent bullock's bones . .	51·0	1·3	...	37·7	10·0	...	Vauquelin and Fourcroy.
A child's first teeth	20·0	...	...	62·0	6·0	12	Pepys.
Teeth of an adult	20·0	...	...	64·0	6·0	10	
The roots of the teeth . . .	28·0	...	...	58·0	4·0	10	
The emanel of teeth . . .	...	...	...	78·0	6·0	16	
The spine softened by disease	79·75	0·82	4·7	13·6	1·13	...	Bostock.

Fourcroy and Vauquelin could not discover the fluate of calcium either in the enamel of the teeth or in recent ivory.

Boiling water extracts slowly the cartilage of bone in the form of gelatin. Cold hydrochloric acid dissolves the salts which have lime for their base, leaving nearly altogether untouched the whole of the cartilage. Ammonia precipitates the phosphate of lime from its solution in warm hydrochloric acid: the phosphate of lime, however, thus obtained, is accompanied with a considerable proportion of gelatin. Bones submitted to dry distillation, give gelatin, and, as a residue, the carbon of bones, which is a compound of animal charcoal and the salts, with potash for their base: exposed to the air, the charcoal of bones passes into the state of ashes.

Tophus, found in the articulations of the arm, consists of animal matter, with traces of adipocire, 56·2; carbonate, phosphate, and hydrochlorate of potash, 3·2; carbonate of lime, with traces of the carbonate of magnesia, 12·5; phosphate of lime, 28·1. Another specimen contained animal matter, with unctuous and fatty matter, and a little soda, 73·0; carbonate of lime, 10; phosphate of lime, 17.*

The concretions found in persons subject to the gout are composed of the urate of ammonia.†

The marrow of bones.— The medulla of the cylindrical bones of the bullock contain, membranes and vessels, 1; fat, 96; a reddish serum, 3.

The medulla of the lower part of the radius, and of the tibia, contains a very liquid fat, and neither coloured vessels nor membranes.

The diploë of the extremities of the long bones contain fatty matter and a reddish serum, in very variable proportions.

The vertebræ of the dorsal column contain a deep brown serum, partly concrete, soluble in water, and rarely a trace of fat.‡

The cartilages dissolve in water kept for a considerable time at the boiling point, and form a jelly.

The SYNOVIA *of the human subject* consists of a yellowish fat, albumen, which constitutes its chief ingredient, an uncoagulable animal matter, soda, chlorate of potassium and of sodium; and the ashes furnish carbonate and phosphate of lime.§

The synovia of the articulations of the knees of a man was found to consist of a flocculent substance, which coagulated at the temperature of boiling water, and was precipitated by the chlorate of mercury.‖

Gout appears to change, in some degree, the secretion in the joints affected. Dr. Wollaston, Dr. Pearson, and Mr. Tennant, found the chalkstones formed in this disease composed of urate of soda. Fourcroy has confirmed this analysis;

* John, Ecrits Chim. tom. v. p. 104.
† Wollaston.
‡ Berzelius, Nouv. Journ. de Gehl. tom. ii. p. 287.
§ Lassaigne and Boissel, Journ. de Pharm. tom. viii. p. 306.
‖ Bostock.

he therefore conjectures that synovia contains uric acid.*

Synovia of a horse.—*A.* From an articulation which was in a healthy state: soluble albumen, 6·4; animal matter, which did not become concrete with the carbonate and the hydrochlorate of soda, 0·6; phosphate of lime, 0·15; traces of an ammoniacal salt, and of phosphate of soda; water, 9·28. — *B.* From a joint anchylosed in consequence of a wound: insoluble, fibrous albumen; soluble albumen; free phosphoric acid; the same salts as mentioned above.†

Synovia of an elephant. — Reddish, filamentous, of a slightly saline and insipid taste; when warmed or heated by mineral acids it coagulated. It contained a soluble albumen of animal matter precipitated by tannin, and which did not become concrete in a small quantity; soda and hydrochlorate of potash.‡

The periosteum approaches the chemical properties of cartilage, and yields a small proportion of gelatin.

The ligaments resist for a very long time the action of boiling water, but dissolve at last, in part, like gelatin.

The membranes, as the serous (the pia-mater, arachnoid, pericardium, pleura, peritonæum, &c.) and the skin, dissolve in boiling water, and pass to the state of gelatin.

INTEGUMENT.—*Cutis vera*—formed of fibres interwoven like a felt. It yields little gelatin on maceration in cold water; by long boiling in water it becomes gelatinous, and dissolves completely, and by evaporation it becomes glue. Hence it appears to be a peculiar modification of gelatin. By tannin, and the extractive of oak-bark combining with it, leather is formed.

Rete mucosum — "is a mucous membrane, situated between the *cutis vera* and the *epidermis.* The black colour of negroes is said to depend upon a black pigment situated in this substance; but it seems to us to be situated in the inner or flocculent surface of the epidermis. Chlorine deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that gas, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former intensity.§ This experiment was first made by Dr. Beddoes on the fingers of a negro."||

The epidermis possesses the same properties as horn. The internal surface of the epidermis seems to be the seat of the black colour of the negro, and not the rete mucosum. The human epidermis consists of fatty matter, 0·5; animal matters soluble in water, 5·0; concrete albumen, 93 to 95; lactic acid, lactate, phosphate, and hydrochlorate of potash, sulphate, and phosphate of lime, an ammoniacal salt, and traces of iron, 1.¶ The nails of the fingers and toes present an analogous constitution.

HUMAN HAIR may be regarded as fine tubes of a substance similar in all its properties to horn, covered by a white adipocire, (probably furnished by the sebaceous glands of the scalp, and filled with an oily matter, which is either of a greenish black colour, red, yellow, or nearly colourless, according as the hair is black, red, yellow, or white. The ashes of human hair is composed of the hydrochlorate of soda; of the carbonate, sulphate, and phosphate of lime, (and the phosphate of magnesia in that which is white) a considerable portion of silica, oxide of iron in a very marked proportion in black hair, but scarcely to be recognised in that which is white; and a very small quantity of the oxide of manganese.

The sulphur, which is undoubtedly combined in the organisation of the corneous or horny substance, is found more abundantly in the red and light-coloured hair than in the black.

The MUSCULAR FLESH.—The muscular substance is probably composed of very little more than fibrin, traversed by cellular tissue containing fat, by the aponeuroses and tendons, by vessels containing blood, by lymphatics containing lymph, and by nerves. It is, however, very probable that osmazome, lactic acid, the hydrochlorate and phosphate of soda, and the phosphate of lime, particularly belong to muscular flesh, although they are also found in the blood. Cold water extracts of the muscular substance the red colouring matter of the blood, the albumen, the osmazome, and the salts of the blood: boiling water takes up the cellular tissue reduced to gelatin, and the fat which swims on its surface; the residuum consists of fibrin, a little altered by the boiling, and which yields the phosphate of lime by incineration. The muscular substance of beef gives, by incineration, more lime than that of veal.**

According to Berzelius, the muscular texture contains fibrin, vessels, and nerves, 15·8; cellular substance, 1·9; albumen, 2·2; osmazome, with the lactate and hydrochlorate of soda, 1·8; mucous matter, 0·15; phosphate of soda, 0·9; phosphate of lime, containing a portion of albumen, 00·8; water and loss, 77·17.

Bullock's heart. — Osmazome, 7·57; albumen and cruor, 2·76; fibrin, with vessels, nerves, cellular tissue, fat, and phosphate of lime, 18·19; an ammoniacal salt and a free acid, in an indeterminate quantity; lactate of potash, 0·19; phosphate of potash, 0·15; chloruret of potassium, 0·12; water, 77·04.††

An ossification found in the human heart. — It contained a cartilaginous matter and phosphate of lime in nearly equal proportions, with a little carbonate of lime.‡‡

An ossification found in the veins of the human uterus.—Membranous substance and phosphate of lime, in nearly equal quantities, with a little of the carbonate of lime and traces of the hydrochlorates.§§

BRAIN and NERVES. — The hemispheres of the human brain: a reddish-brown liquid fat, leaving phosphoric acid by combustion, 0·7; a white fat, becoming blacker by fusion, and giving rise to much phosphoric acid by combustion, 4·53; phosphorus contained in these fatty substances, 1·5; osmazome, 1·12; albumen, 7·0;

* Fourcroy, tom. ix. p. 224.
† John, Ecrits Chim. tom. vi. p. 146.
‡ Vauquelin, Ann. de Chim. et de Phys. vi. p. 399.
§ Fourcroy, tom. ix. p. 259.
|| Beddoes on Factitious Airs, p. 45.
¶ John, Ecrits Chim. tom. vi. p. 92.
** Hatchett.
†† Braconnot, Ann. de Chim. et de Phys. xvii. p. 388.
‡‡ John, Ecrits Chim. tom. v. p. 159.
§§ Ibid. tom. v. p. 126.

phosphate of potash, muriate of soda, phosphate of lime, and phosphate of magnesia, 5·15; water, 80.

The human cerebellum gave the same results.

Medulla oblongata and spinal chord have the same constituent principles, but they contain more of the fatty matter, and less albumen, osmazome, and water.

The nerves of the human subject contain less of the liquid and crystallisable kinds of fatty matter, but more of the fatty substance which resembles adipocire, and much more albumen than the brain.*

The gray substance of the brain of a calf: albumen insoluble in water, 10·0; an unctuous incrystallisable fat, osmazome, phosphate of ammonia, phosphate of soda, phosphate of lime, phosphate of magnesia, hydrochlorate of soda, and traces of iron, 15·0 to 10·0; water, 75 to 80.

The white substance of the brain of a calf contained more fatty matter than the gray; it presented traces of silica. The cerebellum of the calf gave the same products as the cineritious substance.

The optic thalami, the medulla oblongata, spinal marrow, and the nerves of the calf, gave results similar to those furnished by the white substance of the brain, excepting that they contained more albumen, and less water.

The brain of a bullock contained also phosphate of ammonia, a more solid albumen, a reddish-coloured fat, and a crystallisable fat. The composition of the brain of the stag was similar.†

The lymph found in the ventricles of the human brain: gelatin (osmazome?), 0·9; mucus (salivary matter?), 0·3; albumen, 0·6; hydrochlorate of soda, and a little of the phosphate of soda, 1·5; water, 96·5; loss, 0·2.‡

A soft concretion found encysted in the cerebral pulp of a subject who was afflicted with mental alienation: white grease, 6; semi-concrete albumen, 17·0; cartilaginous substance, insoluble in potash, 18·0; salts, with ammonia, potash, soda, and lime for their base, about 2·0; water, 57.§

See the note at pp. 199 and 200, for the composition of the *humours and textures of the eye*. The pigmentum nigrum is mixed with mucus.

Mucus.—The nasal mucus of the human subject contains:—mucus, 5·33; albumen and salivary matter, with a trace of phosphate of soda, 0·35; osmazome, with lactate of soda, 0·3; soda, 0·09; hydrochlorate of potash and of soda, 0·56; water, 93·37.‖ The mucus of the trachea, according to Berzelius, is similar in its composition.

Saliva has a strong affinity for oxygen, absorbs it readily from the air, and gives it out again to other bodies. The human saliva consists of—salivary matter, 0·29; mucus, 0·14; osmazome, with lactate of soda, 0·09; soda, 0·02; hydrochlorate of potash and hydrochlorate of soda, 0·17; water, 99·29.¶

Salivary calculi are formed of a membranous substance, containing phosphate of lime.

The tartar of the teeth.—Mucus, 1·25; salivary matter, 1·0; animal matter, soluble in hydrochloric acid, 7·5; phosphate of lime and phosphate of magnesia, 7·90.**

The Lachrymal Fluid.—Animal matter, soda, hydrochlorate and phosphate of soda, and phosphate of lime, 1·0; water, 99·0. The calculi of the lachrymal gland are formed of the phosphate of lime.††

The Gastric Juice.—The gastric juice ejected by vomiting, after fasting for some time, resembled, according to Montegre, the saliva; it contained flocculi of mucus, and underwent putrefaction as rapidly as the saliva; but sometimes it was acid, and then it did not undergo putrefaction.

Lymph.—The liquor found in the thoracic duct of animals which have not taken nourishment for twenty hours, is as limpid as water, does not affect the vegetable colours, and does not coagulate either by heat or by acids; it becomes slightly turbid from alcohol, leaves a very small residuum when submitted to evaporation, and consequently appears to contain but very little matter, and only a small quantity of the hydrochlorate of soda.

The lymph of a horse taken from the thoracic duct towards the inguinal region and meso-colon, was of a greenish yellow, translucid, and concreted in twelve minutes into a clear gelatin; the coagulum, which hardly amounted to $\frac{1}{100}$, was similar to fibrin, the fluid contained about 0·04 of albumen, muriate of soda, with a little soda and phosphate of soda.‡‡

Chyle.—The chyle taken from the thoracic duct of a dog, three hours after a vegetable diet, resembled clear milk, and deposited a reddish-white coagulum: this coagulum, which had the appearance of fibrin, was to the serum at first in the proportion of 48 to 100; but after being left longer to itself it increased considerably. The specific weight of the serum was 1·018; it did not coagulate at the temperature of boiling water, but became turbid; after some weeks it became a little sour, without undergoing putrefaction: in 100 parts it contained from 4·8 to 7·3 of solid matter, which consisted of 0·9 of soluble albumen and salts; it contained neither gelatine, nor phosphate of lime, nor any ammoniacal salt.

The chyle of a dog, collected three hours after having eaten meat, had the appearance of cream: its coagulum, a little red, was to the serum at first as 46·5 to 100, but this quantity diminished gradually: the serum became much more turbid by heat, and by the addition of acids, than that produced from vegetable food; it underwent putrefaction in three days; it deposited, when allowed to stand, a white and greasy cream, and furnished from 7 to 9·5 per cent. of solid matter, consisting of soluble albumen, without any gelatin. Brande observed a substance analogous to the sugar of milk in the serum.§§

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* Vauquelin, Ann. de Chim. lxxxi. p. 37.
† John, Ecrits Chim. tom. iv. p. 249; tom. v. p. 162.
‡ Haldat, Ann. de Chim. cx. p. 175.
§ John, Ecrits Chim. tom. v. p. 102.
‖ Berzelius, Fourcroy, and Vauquelin.
¶ Berzelius, Bostock, Thomson, John.
** Berzelius.
†† Vauquelin.
‡‡ Reuss and Emmert, Journ. de Scherer, tom. v. p. 681.
§§ Marcet, Vauquelin, Brande, &c.

Chyle, "when drawn from the thoracic duct, about five hours after the animal has taken food, is an opaque liquid, of a white colour; without smell, and having a slightly acid taste, accompanied by a perceptible sweetness. The presence of a free alkali is indicated. About ten minutes after it is drawn from the animal it coagulates into a stiff jelly, which in the course of twenty-four hours gradually separates into two parts, producing a firm contracted coagulum, surrounded by a colourless fluid."

1st. "The coagulum, as appears from the experiments of Vauquelin,* is an intermediate substance between albumen and fibrin. He considers it albumen on its way to assume the nature of fibrin. It is not so stiff nor of so fibrous a texture as fibrin; it is more easily acted on and dissolved by caustic alkalies; it is insoluble in alcohol and ether, readily dissolved by sulphuric acid, very dilute; nitric acid converts it into adipocire. When burnt, it leaves a charcoal containing common salt, phosphate of lime, and gives traces of iron."†

2d. The liquid portion separates albumen on boiling, and contains sugar and a very small portion of a fatty matter, similar to that found in brain. The same salts as in other animal fluids.

Blood.—Taste slightly saline, smell peculiar, specific gravity 1·0527. As soon as the vital influence of the vessels ceases to act on the blood, it separates into the coagulum or cruor, and serum. The common proportion is one part of cruor to three of serum. The proportion, however, varies from 1·2 to 1·4. If the separation of fibrin, giving rise to the coagulation, takes place in repose, the fibrin entangles the red particles of the blood; but if the blood be kept in motion, the red particles escape into the serum, and the fibrin is separated into threads.

1st. *Serum.*—Possesses the taste and smell of the blood; specific gravity is about 1·0287.

Berzelius found that the serum of human blood was composed as follows:—water, 905·00; albumen, 80·00; muriates of potash and soda, 6·00; lactate of soda, with animal matter, 4·00; soda, phosphate of soda, with animal matter, 4·10; loss, 0·90=1000·00.‡

"Dr. Marcet found the constituents of serum as follows:—water, 900·00; albumen, 86·80; muriates of potash and soda, 6·60; muco-extractive matter, 4·00; sub-carbonate of soda, 1·65; sulphate of potash, 0·35; earthy phosphates, 0·60=1000."§

"The muco-extractive matter was, doubtless, impure lactate of soda." "Berzelius is of opinion, that the sulphate of potash, and the earthy phosphates which were found by Dr. Marcet in the ashes of serum, were formed during the incineration; for phosphorus, sulphur, and the basis of lime and magnesia, exist, according to him, as constituents of albumen."

"Gelatin was considered as a constituent of serum until Dr. Bostock and Professor Berzelius proved that the opinion of its existence in blood was not well founded."

2. *The cruor*, or the clot.—Specific gravity about 1·245. Is separated into two portions by ablution in water. 1st, a white, solid, elastic substance, which has all the properties of *fibrin*; 2d, the portion held in solution by the water is the colouring matter, with a portion of serum.

"Berzelius and Brande have shewn that this clot is a compound of fibrin, albumen, and colouring matter of blood. According to the analysis of Berzelius, it consists of—colouring matter, 64; fibrin and albumen, 36=100."

"When the colouring matter is incinerated, about one-third of a per cent of oxide of iron may be extracted from its ashes. This portion of iron is a constituent of the colouring matter, and perhaps the cause of its red colour.‖ But in what way it is united to the albuminous portion of the colouring matter, remains unknown. When incinerated, the colouring matter leaves $\frac{1}{80}$th of its weight of ashes, consisting, according to the analysis of Berzelius (which appears to be the most to be depended on), of the following ingredients:—oxide of iron, 50·0; subphosphate of iron, 7·5; phosphate of lime, with traces of magnesia, 6·0; pure lime, 20·0: carbonic acid and loss, 16·5=100·0."

Berzelius is of opinion that none of these bodies existed in the colouring matter; but merely their bases, iron, phosphorus, calcium, &c.; and that they are formed during the incineration.

"The albumen of blood leaves the same quantity of ashes as the colouring matter; but these ashes contain no traces of iron."

"Dr. Gordon has made it appear probable, that during the coagulation of blood a little heat is evolved."¶

Rouelle has obtained nearly the same ingredients, only in different proportions, from the blood of a great variety of animals.

Fœtal blood.—"Fourcroy made some experiments on the blood of the fœtus. He found that it differed from the blood of the adult in three things:—1st, Its colouring matter is darker, and seems to be more abundant. 2d, It contains no fibrin, but probably a greater proportion of gelatin (?) than blood of adults. 3d, It contains no phosphoric acid."**

Diseased blood.—1st. "Deyeux and Parmentier†† ascertained that the buffy coat consists of the fibrin. The cruor, deprived of this substance, is much softer than usual, and almost totally soluble in water.

2. "The blood drawn from several patients labouring under sea scurvy, afforded scarcely any remarkable properties to these chemists, except a peculiar smell, and an albumen which was not so easily coagulated as usual."

3. The blood of patients in putrid fevers gave no sensible alteration in its properties to the examinations of these chemists.

4. "The blood of diabetic patients: the serum of the blood, according to the experiments of Dobson and Rollo, assumes the appearance of whey. Dr. Wollaston has shewn that it contains no perceptible quantity of sugar, even when the urine is loaded with it."

Milk separates into cream, curd, and whey. 1st, Cream is composed of a peculiar oil, curd, and serum. Cream of the specific gravity of 1·0244, was analysed by Berzelius, who found it composed of—butter, 4·5; cheese, 3·5; whey, 92·0=100·0.

* Ann. de Chim. xxxi. p. 113.
† Thomson.
‡ Annals of Philosophy, vol. ii. p. 202.
§ Medico.-Chirurg. Soc. Trans. vol. ii. p. 376.
‖ Thom. vol. iv. p. 492.
¶ Annals of Philosophy, vol. iv. p. 139.
** Four., Ann. de Chim. tom. vii. p. 162.
†† Journ. de Phys. tom. xliv. p. 454.

2d. Curd may be precipitated by rennet, or the acids: alkalies dissolve it easily. The constituents of curd, according to the analysis of Gay Lusac and Thénard, are as follows :—

Carbon	59·781
Oxygen	11·409
Hydrogen	7·429
Azote	21·381=100·000

Dr. Thomson's application of this analysis to the atomic theory.

7 atoms	Carbon	5·25	60·87	By doubling the number of atoms, it may be compared with gelatin, albumen, and fibrin.	14 atoms	Carbon	10·5
1 —	Oxygen	1·00	11·60		2 —	Oxygen	2·0
5 —	Hydro.	0·625	7·24		10 —	Hydrog.	1·25
1 —	Azote	1·75	20·29		2 —	Azote	3·5
		8·625	100·00		28		17·25

Proust has found in cheese an acid, which he calls the caseic acid, to which he ascribes several of the peculiar properties of cheese.*

The coagulation of curd probably depends upon the same cause as that of albumen.

3. *Whey* still possesses some curd: on evaporation it deposits crystals of sugar of milk. Towards the end of the evaporation, some crystals of muriate of potash and of muriate of soda make their appearance.† According to Scheele it contains also a little phosphate of lime.‡ Fourcroy and Vauquelin, Thénard, Bouillon, la Grange, and Berzelius, have analysed whey. The latter chemist gives the following as the ingredients of milk deprived of its cream:—

Water	928·75
Curd, with a little cream . . . , .	28·00
Sugar of milk	35·00
Muriate of potash	1·70
Phosphate of potash	0·25
Lactic acid, acetate of potash, with a trace of lactate of iron . . .	6·00
Earthy phosphates	0·30
	1000·00

Milk may be made to afford a liquor resembling wine or beer, from which alcohol may be separated by distillation. The Tartars obtained all their spirituous liquors from mare's milk.

It has been ascertained that milk is incapable of being converted into wine till it has become sour; after this, nothing is necessary but to place it in the proper temperature; the fermentation begins of its own accord, and continues till the formation of wine be completed.§ A great quantity of carbonic acid is extricated during the fermentation of milk.‖ Milk is fermented and kept for many months, or even years, in the Orkney and Shetland Islands; but, along with a small portion of alcohol which is formed, the acidity is considerable.

The ingredients of the milk of most animals are nearly the same; the proportion only differs.

The human milk differs from cow's milk—1st, in containing a much smaller quantity of curd: 2d, its oil is so intimately combined with its curd, that it does not yield butter; 3d, it contains rather more sugar of milk.

Parmentier and Deyeux ascertained that the quantity of curd in woman's milk increases in proportion to the time after delivery.¶

None of the methods by which cow's milk is coagulated succeed in producing the coagulation of the human milk.**

Bile (hnman).—The following is the analysis of bile, according to Berzelius: water, 908·4; picromel, 80·0; albumen, 3·0; soda, 4·1; phosphate of lime, 0·1; common salt, 3·4; phosphate of soda, with some lime, 1·0=1000.

Biliary calculi are formed either entirely of cholesterine, or they also contain a yellow concrete mucus, picromel, and rarely phosphate of lime or carbonate of lime. These latter ingredients frequently almost entirely replace the cholesterine.††

Cerumen of the Ear.—Vauquelin considers it composed of the following substances. 1st, Albumen. 2d, An inspissated oil. 3d, A colouring matter:—4th, Soda. 5th, Phosphate of lime.‡‡

Tears.—According to the analysis of Fourcroy and Vauquelin,§§ they are composed of the following ingredients:—1st, Water. 2d, Mucus. 3d, Muriate of soda. 4th, Soda. 5th, Phosphate of lime. 6th, Phosphate of soda.

"The saline parts amount only to about 0·01 of the whole. The mucus contained in the tears has the property of absorbing oxygen gradually from the atmosphere, and of becoming thick and viscid, and of a yellow colour. This property of acquiring new qualities from the absorption of oxygen, explains the changes which take place in tears in some diseases of the eye."

Sweat contains salivary mucus, osmazome, lactic acid, lactate of soda, and hydrochlorate of potass and soda.‖‖

Thénard found it composed of an animal substance analogous to gelatin, acetic acid, hydrochlorate of soda, phosphate of lime, phosphate of iron, and water.

According to Dr. Anselmino,¶¶ the sweat consists of 0·02 of calcareous salts; 0·21 of animal matter with the sulphates; 0·48 of osmazome, and the chlorurets of soda and of lime; and of 0·29 parts of osmazome, combined with the acetates and free acetic acid.

* Journ. de Phys. lxiv. p. 107.
† Parmentier, Journ. de Phys. xxxviii. p. 417.
‡ Scheele, vol. ii. p. 61.
§ Parmentier, Journ. de Phys. xxxviii. p. 365.
‖ Scheele, vol. ii. p. 66.
¶ Journ. de Phys. tom. xxxviii. p. 422.
** Clarke, Irish Trans. vol. ii. p. 175.
†† Gren. Orfila.
‡‡ Fourcroy, tom. ix. p. 373.
§§ Journ. de Phys. tom. xxxix. p. 236.
‖‖ Berzelius.
¶¶ *Zeitschrift für die Physiologie von Fr. Tiedemann, &c.* tom. xi. 2d cah. 1827.

URINE.—The human urine, in a state of health, has a specific gravity of 1·02. It contains urea, 3·01; a matter analogous to saliva, osmazome, lactic acid, lactate of ammonia, and a little urea, 1·724; mucus, 0·032; uric acid, 0·10; phosphate of ammonia, 0·150; sulphate of potassa, 0·371: sulphate of soda, 0·316; hydrochlorate of soda, 0·445; phosphate of soda, 0·294; phosphate of lime, with a little phosphate of magnesia, and a trace of the fluate of calcium, 0·1; silica, 0·003; water, 93·3.*

Besides the constituents of healthy urine, as determined by Berzelius, the following have been occasionally detected in it:—albumen, resin with ulmine, acetic acid, benzoic acid (in infants), carbonic acid, sulphur, chloruret of potassium, and iron.

Urine which is excreted in the morning generally contains more of the saline and solid ingredients. Uric acid abounds most in the urine of individuals who live on animal diet. Urine absorbs oxygen from the atmosphere, and passes into a state of putrid fermentation. This is more or less rapid according to the elevation of the temperature; and the quantity of mucus and albumen present in the urine is considerable.

The urine in *diabetes mellitus* has a specific gravity of from 1·026 to 1·05. It generally contains no urea—sometimes a minute quantity of it. It is remarkable for its quantity, and for the saccharine matter which it holds in solution; the saline ingredients are generally present, but in smaller proportions. As the quantity of sugar diminishes, that of albumen increases, and this latter is replaced, as the disease disappears, by urea and uric acid. The chief difference between this urine and that secreted in *diabetes insipidus*, consists in the absence of saccharine matter from the latter.

Icteric urine is frequently yellow and bitter, and contains the principles of bile.

In *acute dropsy* the urine is generally charged with albumen. When dropsy results from disease of the liver, the urine is brown, and deposits a brown sediment.

SEMEN, when ejected, is the product of two different glands, the one fluid and milky, supposed to be secreted by the prostate gland; the other a thick mucilaginous substance, considered to be secreted by the testes, and in which numerous white shining filaments may be discovered: it has a slightly disagreeable odour, an acrid, irritating taste, and is of a greater specific gravity than water. As this liquid cools, the mucilaginous parts become transparent, and acquire a greater consistency; but in about twenty minutes after its emission the whole becomes perfectly liquid.

This change supervenes without any absorption of moisture from the air, and without its action, taking place equally in close vessels. Semen is insoluble in water before this spontaneous liquefaction, but readily so afterwards.† When semen is kept in a moist air, at about 77°, it acquires a yellow colour, like the yolk of an egg; it exhales the odour of putrid fish, and its surface is covered by the byssus septica. According to Vauquelin, semen is composed of water, 90; mucilage, 6; phosphate of lime, 3; soda, 1=100.

The OVA *from the ovaria of the human subject:* gelatin, albumen, phosphate with an alkaline base in excess.‡

AMNIOTIC FLUID, which surrounds the fœtus, in the human species is of a slightly milky colour, owing to a curdy matter suspended in it, of a weak, pleasant odour, and saltish taste; specific gravity 1·005; is composed of water, about 98·8; albumen, muriate of soda, soda, phosphate of lime, lime, 1·2=100·0.§ A curdy like matter is deposited on the surface of the fœtus, evidently from the liquor of the amnios. Vauquelin and Buniva have shewn that it is different from any thing contained in this fluid; and that it has in its chemical relations a great resemblance to fat. They conjecture that it is formed from the albumen of this liquid, which has undergone some unknown changes. It appears to be of service in preserving the skin of the fœtus from being acted on by the liquor of the amnios, and to facilitate its passage in parturition.

PUS.—Its taste is insipid, and it has no smell when cold. Before the microscope it exhibits the appearance of white globules swimming in a transparent fluid; specific gravity from 1·031 to 1·033. When incinerated, the ashes give traces of iron.‖ It produces no change on vegetable blues. Alcohol thickens pus, but does not dissolve it; nor does it unite with oils. Soluble in sulphuric acid, but separated on the addition of water. The same is the case with nitric acid. Muriatic acid also dissolves it when heated, and it is again separated by water.

The fixed alkaline leys form with it a whitish, ropy fluid, which is decomposed by water, the pus being precipitated. Corrosive sublimate, nitrate of mercury, and nitrate of silver, give a whitish precipitate from its solution, indicating an analogy with albumen.

Expectorated matter yields traces of sulphur, and perhaps also of phosphorus; and it contains the following saline substances:—1st, Muriate of soda, varying from $1\frac{1}{2}$ to $2\frac{1}{2}$ in the 1000 of expectorated matter. 2d, Phosphate of lime, half a part in the 1000. 3d, Ammonia, united probably to phosphoric acid. 4th, A phosphate, probably of magnesia. 5th, Carbonate of lime. 6th, A sulphate. 7th, Vitrifiable matter, probably silica. 8th, Oxide of iron. The whole of these last *six* substances scarcely amount to *one* part in the 1000 of expectorated matter.

The proportion of saline matter and of albumen present in expectorated matter varies much in different circumstances. The thicker it is, in general the smaller is the quantity of the saline matter; whereas, when very thin it is often impregnated with salts, especially with the muriate of soda, to a great degree, and tastes distinctly salt and hot.

Liquor of the pericardium.—Dr. Bostock¶ considers it to be composed of—water, 92·0; albumen, 5·5; mucus, 2·0; muriate of soda, 0·5=100·0.

Liquor of dropsy.—Dr. Bostock found the liquid formed in "*spina bifida*" to be composed as follows: water, 97·8; muriate of soda, 1·0; albu-

* Berzelius.
† Vauquelin, Ann. de Chim. ix. p. 70,
‡ John's Chemical Writings, vol. vi. p. 158.
§ Vauquelin and Buniva, Ann. de Chim. xxxiii. pp. 270, 274.
‖ Gren's Handbuck, tom. ii. p. 426.
¶ Nicholson's Journ. vol. xiv. p. 147.

men, 0·5; mucus, 0·5; gelatin, 0·2; lime, a trace.*

The same kind of fluid obtained from the head of a child of ten years was examined by Dr. Prout. It faintly reddened litmus paper. Its constituents were as follow:—water, 987·18; albumen, precipitated by nitric acid and heat, 1·66; substances soluble in alcohol (fatty adipocirous matter, lactate of soda,) 1·65; substances soluble in water, 9·51—viz. muriates of potash and soda, 6·80; sulphate of soda, and some animal matter not coagulated by heat, 2·71=1000·00.†

Liquor of blisters.—The analysis of Macqueron‡ gives it nearly the same constituents as the serum of the blood: from 200 parts he obtained—albumen, 36; muriate of soda, 4; carbonate of soda, 2; phosphate of lime, 2; water, 156=200.

Human Fæces.—Their colour seems to depend upon the bile mixed with the food in the digestive canal: when too light, it is supposed to denote a deficiency of bile; when too dark, there is thought to be a redundancy of that secretion. The following table shews the analysis of Berzelius:—§

Water	73·3
Vegetable and animal remains	7·0
Bile	0·9
Albumen	0·9
Peculiar and extractive matter, supposed to be formed from picromel	2·7
Salts (*a*)	1·2
Slimy matter, consisting of picromel, peculiar animal matter, and insoluble residue	14·0
	100·0

(*a*) The salts, their relative proportions.

Carbonate of soda	35
Muriate of soda	4
Sulphate of soda	2
Amm. phosphate of magnesia	2
Phosphate of lime	4

Gases existing in the Intestinal Canal.—These may be ascribed to three sources: 1st, from the common air swallowed with food; 2d, from the decomposition of the intestinal contents; and 3d, from the occasional secretion of gas from the mucous surface of the tube.

The gases from the first source are found chiefly in the superior portions of the canal; those from the second source in the lower part; and those from the third are by no means limited in their situation. It is reasonable to suppose that a large proportion of the azote and carbonic acid is derived from this last source.

From the experiments of Magendie and Chevreul, who examined, very soon after death, the gaseous contents of the stomach and intestines of four criminals executed at Paris, the following appear to be the proportions and the relative quantities in the different portions of the canal:—‖

1. *Gases in the Stomach.*

Oxygen¶	11·00
Carbonic acid	14·00
Hydrogen	3·55
Azote	71·45
	100·00

2. *Gases in the small Intestines.***

Oxygen	00·00	00·00	00·0
Carb. acid	24·39	40·00	25·0
Hydrogen	55·53	51·15	8·4
Azote	20·08	88·5	66·6
	100·00	100·00	100·0

3. *Gases in the large Intestines.*

Carbonic acid	43·50		70·0
Hydrogen and carburetted hydrogen	54·7		11·6
Azote	51·03 = 100·00		18·4 = 100·00

4. *Gases in the Cæcum.*

Carbonic acid	12·5
Hydrogen	7·5
Carburetted hydrogen	12·5
Azote	67·5
	100·0

5. *Gases in the Rectum.*

Carbonic acid	42·86
Carburetted hydrogen	11·18
Azote	45·96
	100·00

* Nicholson's Journ. vol. xiv. p. 145.
† Ann. of Phil. vol. xvi. p. 151.
‡ Ann. de Chim. vol. xiv. p. 225.
§ Gehlin's Journ. vol. vi. p. 536.
‖ Ann. de Chim. et Phys. tom. ii. p. 292.
¶ The oxygen seems to be absorbed by the blood before it reaches the small intestines.
** Results in the different individuals.

THE END.

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